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ABSTRACT

This manual for supervisors of rehabilitation workshops or plants focuses on knowledge, techniques, and application of work simplification and production standards. Four chapters providing introductory material discuss common goals of rehabilitation and production and human factors. The first of seven chapters (chapter 5) on work simplification defines it, weighs advantages/disadvantages, and discusses implementation. Two chapters focus on making and using flow diagrams and process charts. Other topics discussed (chapters 8-11) include use of an operation chart or operations process chart, principles of motion economy, workshop efficiency, and laying out a work place or production line. The section on production standards contains basic information and more advanced materials. Chapters 12 and 13 define work measurement and outline a quick method to set a production standard. Chapters 14, 15, and 17 provide materials for more precise determination of production standards--time study, work rating, and allowances in setting performance standards. Chapters 16 and 18, on predetermined time systems and the learning curve, are intended for those who estimate or set production standards or estimating production outputs for pacing, bidding, or production scheduling purposes. (Most material is in outline format. Forms, examples, and exercises are provided.) (YLB)

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A MANUAL ON

PRODUCTION IMPROVEMENT
in a
REHABILITATION WORKSHOP

REPRINT NO. 17

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Associate

U.S. DEPARTMENT OF HEALTH.
EDUCATION & WELFARE
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EDUCATION

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1. HOW CAN YOU USE THIS MANUAL?

Introduction

This manual has been prepared for you to use in your workshop. It will try to help you:

1. Learn more about two important areas of industrial engineering--work simplification and production standards,
2. See how to apply this knowledge to problems found in most workshops, and
3. Find ways to improve your own workshop.

You may be a leadman, lead worker, or crew leader; a work supervisor or foreman; a department or section supervisor; a production or workshop supervisor; an operations manager or plant manager. Or you may be the workshop director, executive director or general manager. No matter what your job, you have some responsibility to establish ways in which work shall be done. So this manual is for you--the person who selects and controls how other people do their work.

It doesn't matter how many people look to you for leadership. The knowledge and techniques of work simplification and production standards are the same. Of course, the higher your rank in your organization, the greater your opportunity to set the stage and encourage--even require--good practices in work simplification and production standards.

Even if you supervise only two or three others, you can see that their work is done in the right way. In fact, as a first line supervisor, you will often have the best opportunity to demonstrate that the techniques of work simplification really do work.

In some places in this manual, you will notice that facts or ideas are numbered and listed in outline form. This is intended to make it easy for you to get the main points quickly. But this calls for a few words of caution. Remember, in normal reading you skip over some words and phrases to get to the author's ideas. In outlines, however, extra words which give flavor are eliminated; only the core points remain. So you should read the outlines slowly, carefully--perhaps twice or even three times. Think of how these ideas relate to ideas or facts you already know. You will thus supply the real meaning to enrich the frame provided by the outline.

As you read this manual, notice that a question appears at the beginning of each section. We all tend to learn better when we are seeking answers to questions. Each of these questions is asked in the hope that you will say to yourself, "I want to know...." When you came to the beginning of this section, for example, you might have said to yourself, "I want to know the answer; how do I use this manual?" So on each page you will find materials--facts, ideas, concepts--which answer the question asked at the beginning of that section.

2. WHAT ARE THE COMMON GOALS OF REHABILITATION AND PRODUCTION?

The title of this manual, "Production Improvement in a Rehabilitation Workshop," might imply that to improve production in such workshop, special techniques are needed. That's not so. If you study the elements business finds essential for success, you will find that the same elements are needed for a workshop to succeed in its job of rehabilitating people for work.

Aside from the element of luck, both the successful business and the successful workshop need:

1. Mature leadership--a boss who is stable and grown-up emotionally.
2. A clear sense of direction--for if you don't know where you are going, any road will do.
3. Adequate financing--insufficient capital is mainly responsible for the fact that 80% of all new businesses disappear within five years.
4. Intelligent, constructive supervision--foremen who know and understand the human factor.
5. A modern, well-equipped physical plant--working conditions and tools should contribute to the production process, not hinder it.
6. A businesslike work atmosphere--real work can be done neither in a grim dungeon nor a country club.
7. Good work methods--use of the "better way" in material handling, job layout, and laborsaving jigs and fixtures.
8. Performance standards--time standards for production workers, and satisfactory performance measures for clerical workers and staff.
9. Adequate records--of production, payroll, expenses, sales, income and personnel.
10. Real communication--between workers, staff and administration.
11. Understanding of the market--in which the company's products are sold.

Although there are business firms which lack some of these elements and still appear to operate profitably, their chance for long-term survival is substantially lowered if enough of the eleven key elements are missing.

It is hard to find any element in this list which a rehabilitation workshop can do without.

Because good work methods and performance standards are frequently neglected in workshops, they are the focus of our attention in this manual. But here are some additional reasons why these subjects belong in any training program for workshop personnel:

1. Development of work methods through work simplification is often a means of evaluating or helping the client in his workshop experience.
2. Work simplification is specific, concrete and demonstrable.
3. Work simplification is more easily controlled than some of the other elements previously listed.

4. Because it uses an analytical approach, work simplification can lead to improvements in other areas of workshop function.

5. Interest in work simplification must be renewed periodically even by those who have had formal training or experience in it.

6. Fair production standards can be established only after good work methods have been selected and specified.

3. ARE THE ATTITUDES OF PEOPLE TOWARD CHANGE IMPORTANT?

Before we look at a person's attitude toward change, we should look at what the ordinary worker wants from his job.

1. OPPORTUNITY to be doing something useful from his point of view.
2. RECOGNITION of self worth and of his accomplishments.
3. BELONGING or the feeling that he is a part of a group with which he identifies.
4. SECURITY or the ability to plan ahead with confidence so far as job retention, financial obligation, etc., are concerned.

What a worker does in his job does not always give him what he wants from the job. But he does try to gain as much opportunity, recognition, belonging, and security as he can. Hence, whenever changes are suggested, his usual reaction is to ask: what will I gain, what will I lose from this. He will look with suspicion on most new ideas. To counter this normal and natural resistance to change, the worker must be helped to feel he will gain something, or will avoid losing something.

Resistance to change may be a symptom of:

1. Resentment of criticism--whether or not criticism was intended or implied.
2. Fear of the unknown--a threat to security of job, income, status.
3. Ego involvement with present or old methods.
4. Natural persistence of established habits.
5. A concealed attack on a supervisor who is not accepted.

Problems which might be encountered from workers when methods are changed include:

1. Slowdowns, slow to learn new ways
2. Won't use new methods
3. Sabotage of new method
4. Complaints that new method is tiring
5. Complaints that they will have to work harder
6. Increases in other grievances
7. Comments that new methods will work people out of their jobs
8. Comments that rates will be cut

Reasons for the problems which may arise when methods are changed:

1. Fear of the unknown
2. Fear of losing jobs
3. Distrust of management
4. Failure to understand what work simplification really is
5. Lack of information about new method
6. A feeling that the new methods make them less important

A person's attitude toward the changes you suggest will, more than any other factor, determine whether or not they are accepted and adopted. Securing a favorable attitude from your workers or your boss is as important as the worth or value of the change itself. A poor attitude can render the best idea for change worthless. A good attitude toward change, however, can utilize almost any idea and produce improvements in excess of the original value of the idea.

3A. CAN THE NATURAL RELUCTANCE TO ACCEPT AND ADOPT CHANGES BE OVERCOME?

Ways to overcome problems and gain employee acceptance of new methods:

1. Give information

    Why method is being used
    How it will work
    When it will go into effect
    Who will be affected
    Where will it be put into effect
    What is to be changed

2. Get participation

    In planning stage and testing stage
    Solicit suggestions
    Provide time for questions

3. Provide training in the use of the new methods
4. Use tact!!

Keeping people informed and creating opportunities for them to become involved in finding and selecting changes which affect their work will virtually assure that your improvements will be accepted.

You will also find that the employees who report to you have many ideas which can lead to beneficial changes.

The secret in both cases is to recognize that the word "your" is three-fourths "our." An employee can take a very dim view of "your" changes, but he has much at stake and will work hard for them when they are "our" changes.

To make effective use of work simplification, you need supervisors who:

1. Get satisfaction from innovating
2. Gain the involvement and interest of their workmen
3. Will teach and demonstrate
4. Will follow-up to be sure changes are understood

4. HOW CAN A QUESTIONING ATTITUDE BE DEVELOPED?

People who are successful in using either a common sense or the formal systematic approach to work simplification have characteristic ways of thinking.

The state of mind required includes:

1. Belief that there is always a better way to do a job
2. Knowledge that the "one-best-way" is never achieved
3. Realization that the theory and techniques of work simplification can be applied to almost any job or process
4. Possession of the valuable tools of curiosity, questioning, and imagination
5. Attitude that nothing is sacred about the present methods being used

When you have a willingness to be critical, you are ready to embark on work simplification. "Critical" as used here is a constant looking for ways things can be done differently; not the destructive, fault-finding kind associated with criticism.

As Kipling said:

> "I keep six honest, serving men;
> They taught me all I knew.
> Their names are what, and why and when,
> And how and where and who."

Of Kipling's inquiring men, "Mr. Why" usually does the best and most productive questioning.

5. WHAT IS WORK SIMPLIFICATION?

The definition of work simplification is the organized application of common sense by everyone to eliminate waste of any kind--of time, energy, materials, space, or equipment.

You don't have to be an engineer or expert to know that a workman taking 12 steps to get material is wasting both time and energy if the material could be located closer.

But work simplification has been developed as a tool of production. It is a system of finding better ways to do work and of putting the better ways into effect.

Work simplification can be used in all types of work problems. It is equally suited to the production line of the workshop; the warehouse; the office; or even in our homes in the kitchen, laundry, bathroom or dressing room. It can be very simple or extremely complex.

In summary, work simplification seeks to:

	Key Word
1. Reduce the effort required of workers	--easier
2. Improve productivity	--quicker
3. Eliminate waste	--cheaper

The principles of work simplification include:

1. Productive activities are stressed. Non-productive activities should be eliminated or reduced to a minimum.
2. A smooth flow of activity should be laid out from operation to operation in a process, or a balanced pattern arranged for an operator at a work place.
3. Activity should be as simple as possible--avoid the Rube Goldburg way.
4. Participation of the people involved can be best secured by:
   - a. Prepare their understanding of work simplification in advance
   - b. Give them sufficient "know how" to apply it to their work
   - c. Stimulate their interest, initiative, and imagination by showing and dramatizing results. Such participation should lead to enthusiastic cooperation

5A. WHAT ARE THE ADVANTAGES AND DISADVANTAGES OF WORK SIMPLIFICATION?

Advantages

To employees:

1. Safer work
2. Less fatiguing work
3. Less boring work
4. Improved morale
5. (Often) higher wages due to increased productivity

To workshop:

1. Reduction of waste and costs
2. Increased productivity
3. Improved quality of products manufactured
4. Improved customer service
5. Development of a climate which is more receptive to change
6. Assists development of an analytical approach to problems
7. Eliminates bottlenecks
8. A systematic and orderly approach will yield better results than a haphazard or inspirational approach
9. Yields up-to-date competitive work methods
10. Improves rehabilitation results through better and more employable work skills of clients

To supervisors:

1. Your job becomes easier as the morale of your people improves
2. You have better relations with your people
3. Standardization of methods gives you more time to deal with the human problems on the job
4. You get personal satisfaction from leading an effective team
5. You have pride in a job well done
6. It adds interest and challenge to your work
7. It helps make your job more secure

Disadvantages

You must guard against:

1. Stirring up problems which can't be solved due to shortage of work, money, etc.
2. Calling on already overburdened supervisors
3. Proposing changes which will not reduce costs enough to repay the expense of the study and change-over
4. Creating problems with incentive pay systems which would have to be changed

5B. WHERE CAN WORK SIMPLIFICATION BE APPLIED IN A WORKSHOP?

Work simplification can be started in any of the following places. They are listed in the usual order of attention:

1. Layout: The locations of raw materials, work station, and finished products in the plant.
2. Material Handling: Distances and equipment.
3. Sequence: The order in which the steps or operations are performed.
4. Work Methods: How the employee does his job, manner of performing the operation.
5. Layout: The locations of materials, tools, equipment, and jigs in the work stations.

6. Equipment: Used in production.

7. Product Design: The physical properties of the product: specifications, tolerances, appearance, and functional use.

8. Materials: Used in the product and as supplied to facilitate its production.

First line supervisors or foremen have their greatest opportunity to influence the work methods and sequence of work operations of the workers over whom they have control.

Workshop directors or managers should first look to the layout and material handling factors. Then supervisors should be trained who will carry out work simplification in their own areas of responsibility.

Equipment changes should be more frequently examined. The use of labor saving machinery in workshops for the handicapped is sometimes opposed by those who think they are doing the clients a favor. Nothing could be further from the truth. Antiquated, inefficient tools in a skilled workman's hands is sufficient in itself to handicap him. When handicapped clients are forced to use obsolete equipment, they are burdened with a double handicap--their own and the one imposed by the machinery (or lack of it).

Product design and the selection of materials is generally up to the customer for contract shops. However, suggestions a workshop can make based on its experience with similar products which saves the customer's money can result in a very favorable relationship.

In shops where prime manufacturing is carried on, design and use of the most suitable material is extremely important, since material costs are two to four times greater than direct labor costs on the average.

5C. WHAT STEPS DO YOU TAKE TO SIMPLIFY WORK?

1. Select the job to be improved. Jobs which:
   a. Are bottlenecks
   b. Involve large amounts of labor--either in one chunk or a repetitive basis
   c. Require a lot of walking
   d. Have a large proportion of "make ready" and "put away"
   e. Have workers with considerable amounts of idle time, idle equipment
2. Apply the elimination approach
   a. Identify the overall reason or purpose or intent of the job. Question: Is it still needed?
   b. Are there any alternatives?
   c. Is there any duplication?
3. Study the job in detail
   a. Use flow diagrams, process charts, or operation charts as appropriate

4. Question each step of the job
    a. Why is each "do" operation necessary?
    b. Why are other steps necessary?
    c What is being done--could it be eliminated, done in some other way?
    d. Where is it done--why here, could it be done at another place?
    e. When is it being done--why now, could it be done at another time?
    f. Who does it--why this person, who else could do it?
    g. How is it being done--why this way, what other ways could it be done?
5. Develop alternate proposals for improved methods
    a. What questions lead to eliminations, especially of moves and storages
    b. Where, When and Who questions lead to combining and rearranging
    c. How questions lead to improving
6. Select the best proposal
    a. It is important to have several thought-out proposals
    b. Reject those which are not feasible
    c. Compare the remaining in terms of:
        1) operating cost changes--labor and overhead
        2) installation costs
        3) other changes affecting: quality, personnel, safety, production capacity
7. Sell the selected proposal to management and the workers
8. Put the improvement into effect
9. Check back to see that the changes are being used and are producing the expected results

5D. WHAT ARE THE TOOLS AND TECHNIQUES OF WORK SIMPLIFICATION?

Work Simplification Forms

It is important to recognize the function of the forms and charts which are used in work simplification. They are not essential in making work simplification improvements. In fact, if you have been in the habit of continuously improving work operations in your workshop, you have undoubtedly been using some of the ideas of work simplification without the specialized charts and forms. This is not to say that these devices are of no use. Quite the contrary, they have been found over years of use to be of great value in gathering and visualizing information about the way work is being performed in many industrial production and office situations. They are tools which must be used to fashion changes. They are not, in themselves, the end product.

We shall concentrate on two of the most useful of these forms:

1. The Flow Diagram
2. The Process Chart

In addition, three other forms are used in more advanced work simplification. Although they will not be explained in detail, nor used in training sessions with this manual, you should know of their existence. They are:

3. The Activity Chart (sometimes called a man-machine chart, a multiple activity (crew) chart, etc.) which shows how long each is working or is idle.
4. Operation Chart (sometimes called a left hand - right hand chart, an MTM chart, etc.)
5. Operations Process Chart which shows what operations are performed, the order in which they are performed, and the points at which materials are added.

Principles of Motion Economy

Knowledge of the human body's ability to perform work is called:

6. Principles of Motion Economy

Personal Skills

Techniques which are supplied by you, the supervisor, include

1. Observation
2. Questioning
3. Analysis
4. Innovation
5. Selection
6. Testing

It should be remembered that the use of these tools and techniques should be limited to an activity or work operation which is important enough so that even a slight reduction in time required for its completion will be a worthwhile benefit to the workshop.

They are used to:

1. Explain a present work method
2. Improve a present work method
3. Plan a new process

6. HOW CAN YOU MAKE AND USE A FLOW DIAGRAM?

The flow diagram should be the first device used in analyzing the overall performance of a job, a department, or a section within a workshop; or of the entire workshop. It is literally a road map which traces the flow of materials or movements of persons in the production process. Using it helps to pinpoint:

1. Long moves between operations.
2. Small volume items, or low production work areas located on the most direct line-of-flow
3. Backtracking.
4. Large volume items or high production work areas on long routes or through out-of-the-way corners.
5. Storage areas which interfere with material flow.

Material handling and the travel of people predominate the flow diagram considerations.

The flow diagram is a sketch of the work area, preferable to scale. It shows the path taken and the distances travelled by the materials or person being studied.

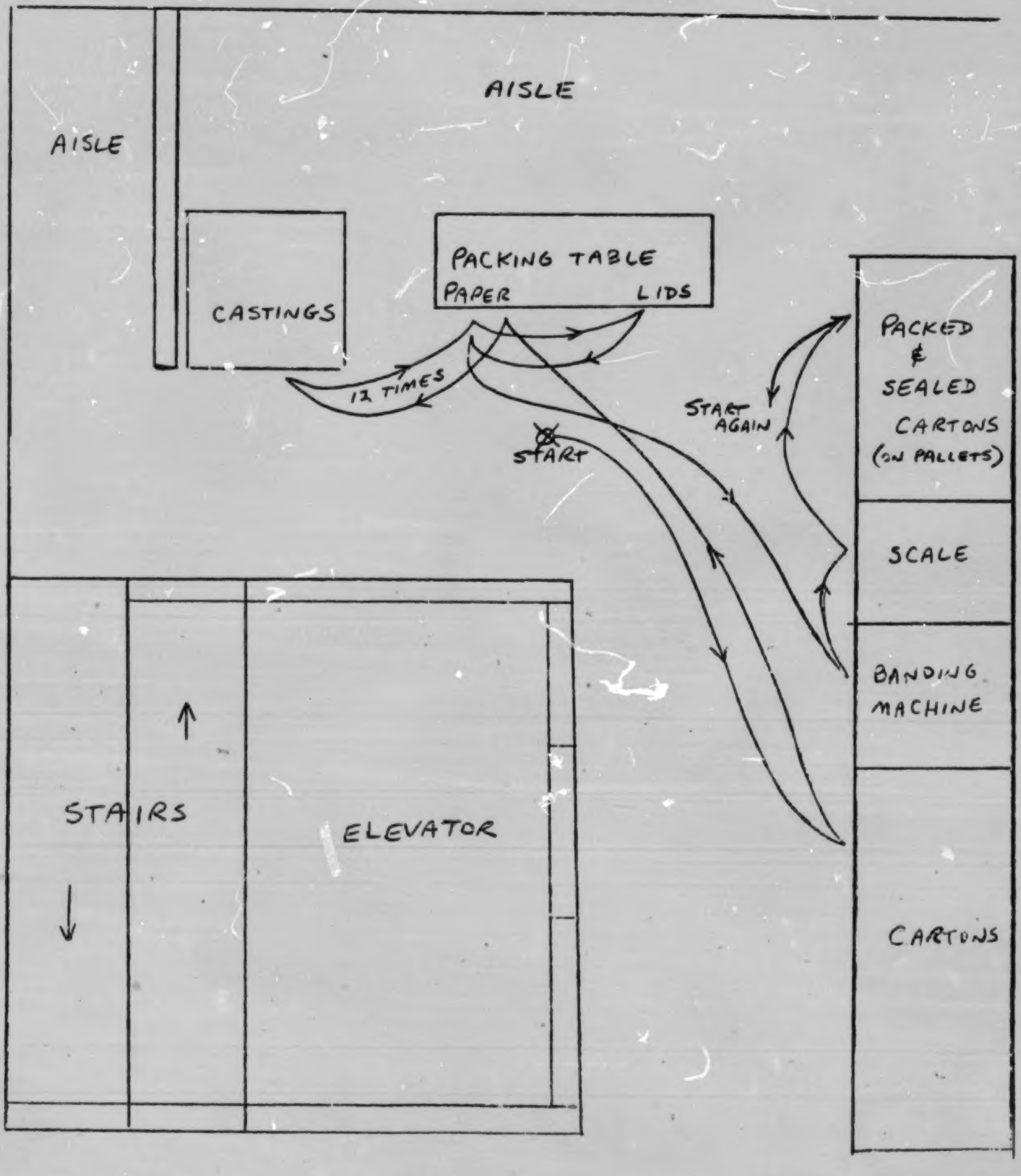
It may be a simple sketch or a more detailed drawing like the ones which follow on the next three pages.

Present
Improved Method

FLOW DIAGRAM

Date__________ Subject____________________

By__________ Chart ___ of ___

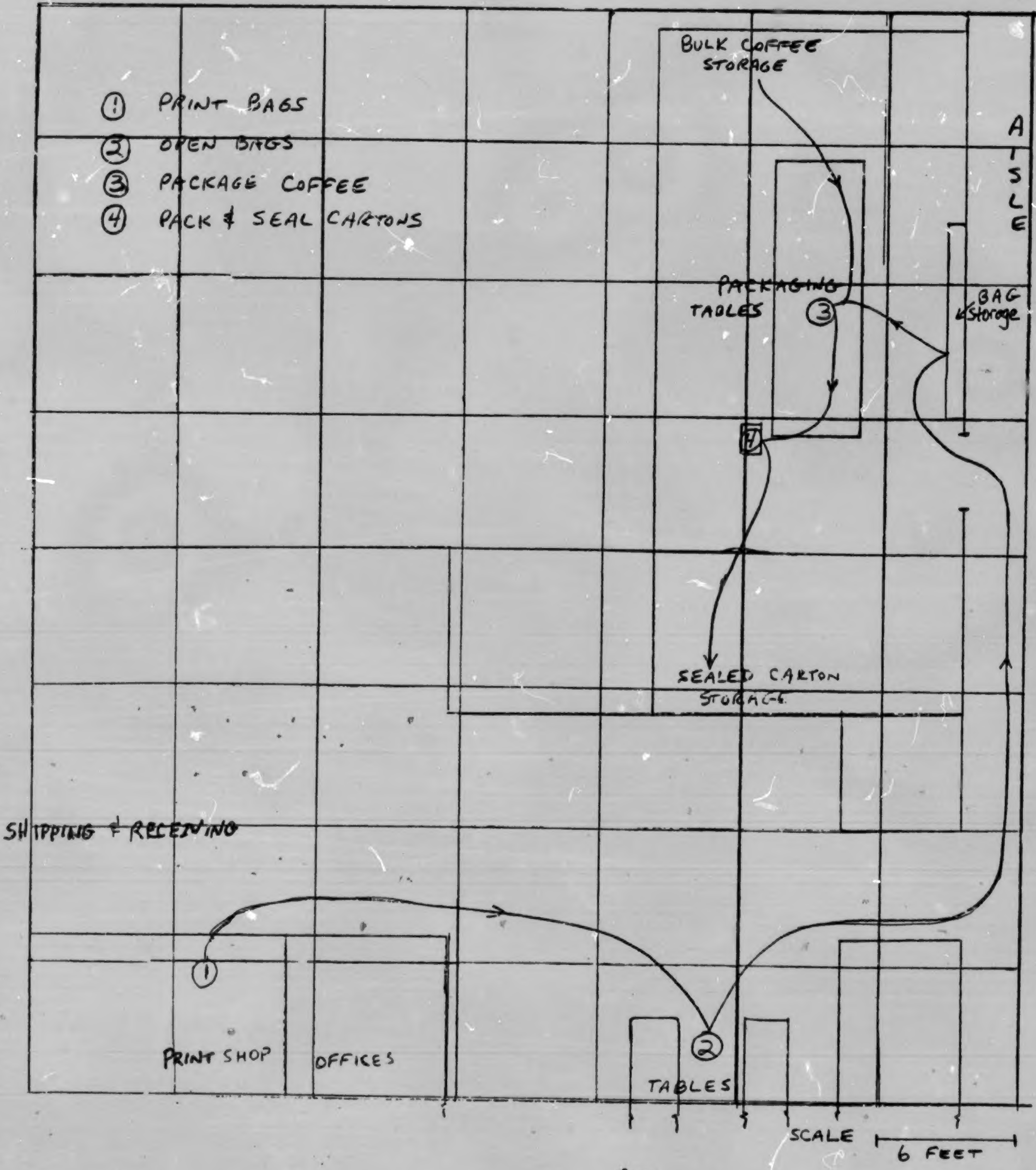

AISLE
AISLE
CASTINGS
PACKING TABLE
PAPER
LIDS
12 TIMES
START
START AGAIN
PACKED & SEALED CARTONS (ON PALLETS)
SCALE
BANDING MACHINE
CARTONS
STAIRS
ELEVATOR

[✓ Present] Improved Method

FLOW DIAGRAM

Date 9/16/65 Subject Instant Coffee Packaging

By JWC Chart ___ of ___



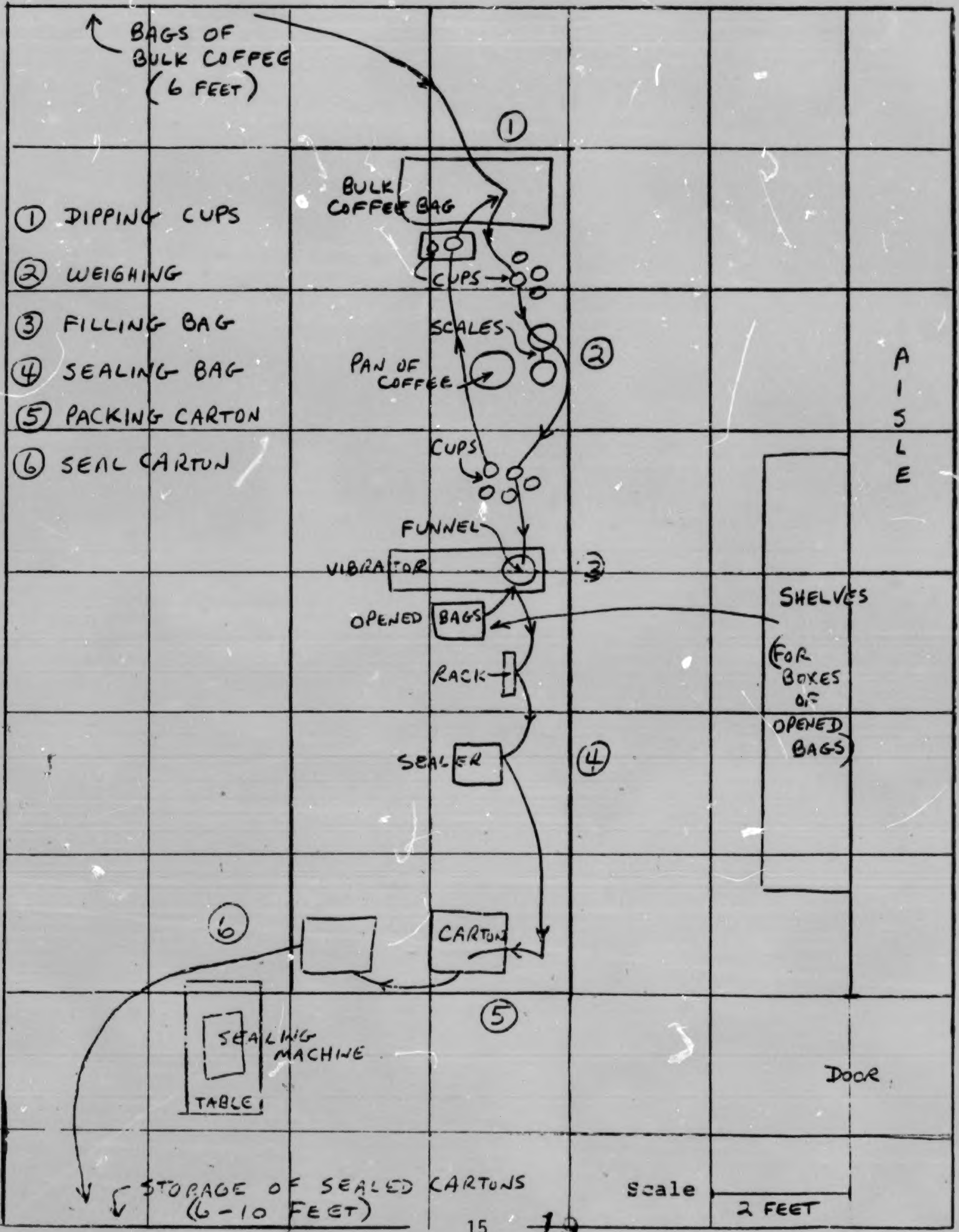
① PRINT BAGS
② OPEN BAGS
③ PACKAGE COFFEE
④ PACK & SEAL CARTONS
BULK COFFEE STORAGE
A I S L E
PACKAGING TABLES
③
BAG Storage
④
SEALED CARTON STORAGE
SHIPPING & RECEIVING
①
PRINT SHOP
OFFICES
②
TABLES
SCALE
6 FEET

Present
Improved Method

FLOW DIAGRAM

Date__________ Subject____________________

By__________ Chart ___ of ___ ____________________


BAGS OF BULK COFFEE (6 FEET)
①
BULK COFFEE BAG
① DIPPING CUPS
② WEIGHING
③ FILLING BAG
④ SEALING BAG
⑤ PACKING CARTON
⑥ SEAL CARTON
CUPS
SCALES
②
PAN OF COFFEE
AISLE
CUPS
FUNNEL
VIBRATOR
③
SHELVES (FOR BOXES OF OPENED BAGS)
OPENED BAGS
RACK
SEALER
④
⑥
CARTON
⑤
SEALING MACHINE
TABLE
DOOR
STORAGE OF SEALED CARTONS (6-10 FEET)
Scale
2 FEET

Make a flow diagram of your morning routine of bathing and dressing involving your bedroom, bathroom and related clothes closets, etc., or make a flow diagram of activities in setting the table for a meal in your home or of the preparation of a meal in your kitchen.

6A. WHAT MATERIAL HANDLING METHODS SHOULD YOU CONSIDER IN A FLOW DIAGRAM?

1. Hand Systems
   1. a. Tote boxes: Available as corrugated boxes at low cost for light parts or as metal or wooden boxes.
   2. b. Barrel dolly: A frame with casters for use under a steel or fibre barrel.
   3. c. Two wheel hand truck: For fast moving of stacks of cartons, boxes, or barrels.
   4. d. Four wheel platform truck: For moving larger quantities of cartons or stackable items which are put on and removed by hand.
   5. e. Four wheeled, box-like canvas trucks, also made of plywood or metal: For moving loose, bulk material which needs a container with sides. Filling is easier than emptying.
   6. f. Pallet dollies: A frame with rollers which will hold a loaded pallet but can be easily pushed and moved short distances by hand.
   7. g. Pallet jacks: A wheeled device to lift pallets or skids a few inches off the floor so they can be moved by hand.
2. Industrial Truck Systems
   1. a. Electric fork lifts: To raise and stack pallets or skids. Available in models to be pushed around by hand, powered movement with operator walking, or full riding models. Requires higher initial cost but has lower operating cost. Clean and quiet operating.
   2. b. Bottled gas fork lifts: To stack and move pallets or skids. Cleaner operating than gasoline trucks.
   3. c. Gasoline fork lifts: To stack and move pallets or skids. Also available to grip round or square materials eliminating the need for pallets.
3. Gravity Conveyor Systems
   1. a. Roller conveyors: For irregularly shaped materials.
   2. b. Skate wheel conveyors: For cartons or smooth bottomed items. Also can be used with flat, reusable boards on which materials are stacked.
   3. c. Slides: Smooth metal chutes.
   4. d. Spiral chutes: For vertical delivery without using much space.
4. Powered Conveyor Systems
   1. a. Roller and skate wheel conveyors combined with a driven belt: Permits movement along a level surface.
   2. b. Belt conveyors: For moving on a level surface or for up a slope.
   3. c. Moving chain in floor or overhead: To which carts or parts can be attached to pull them around a fixed pathway.
5. Storage Systems
   1. a. Pallets: Low wooden platform usually made of 2x4's sandwiched in 1" lumber or plywood so fork lift trucks can move or stack it.

b. Skids: Low wooden platform made of 2x4's or 2x6's with a top deck of 1" lumber or plywood so either fork lift trucks or pallet jacks can move it.

c. Pallet boards: Sheets of hardboard, plywood, or corrugated paper board which are interspersed between layers of cartons stacked on the floor or on pallets or skids to add stability to the stack. Also used on top of a pallet stack to evenly distribute the weight of another pallet load which is placed on top.

d. Shelves or pallet racks: Of pipe and plywood with special clamps which allow it to be easily changed or moved without loss of materials, of slotted angle iron and plywood providing easy construction and adjustment of shelf spacing.

6B. HOW CAN YOU USE A FLOW DIAGRAM TO IMPROVE PLANT LAYOUT?

Good layout requires:

Placing the proper equipment
In the right place
To permit processing the item by the best method
Through the shortest possible distance
In the shortest possible time

Danger signals of poor layout:

1. Congestion of materials or in process assemblies
2. Excessive work in process
3. Long transportation
4. Production bottlenecks
5. Excessive material handling by skilled operators
6. Long production cycles
7. Idle equipment

Types of layouts:

1. Fixed position: Material stays in one place, tools, machinery, and men are brought to it.
2. Process: All operations of the same type are grouped together.
3. Product: Machinery and work stations arranged in a sequence as needed for the processing or assembly of a product.

Considerations in layout design:

1. Weight and volume of material to be handled.
2. Storage requirements: Warehouse, at work station, surge piles.
3. Number of different handlings and available methods.
4. Sequence and distances of material flow.
5. Necessary aisle width to accommodate material handling equipment, pallets, hand trucks, etc.
6. Access for sampling and inspection.

7. Visual supervisory control.
8. Locations of rest rooms, drinking water, lunch rooms, etc.
9. Locations of utilities, compressed air, lighting, heating, ventilating, air conditioning, etc.
10. Relationships to supporting services: maintenance, timekeeping, shipping and receiving, etc.
11. Adaptability and flexibility to changes, expansions.
12. Future growth needs.
13. Cost of changes.

Layout problems occur when a subcontract or manufacturing process is to be analyzed so floor space can be assigned in both the warehouse or storage area and on the production floor.

The factors to be considered include the:

1. materials which are involved
2. machinery to be used
3. work operations to be performed
4. quantity of output required in total and amount expected from each worker
5. methods of material handling to be used
6. production schedule to be followed

Data on materials must be provided for the:

a. raw materials
b. semi-finished or finished component which goes to make up a final product in later assembly or manufacturing
c. surge pile of materials, semi-finished component or finished product at each work station
d. finished product

For each of the above forms of material the following information must be supplied:

1. cubic size of the standard sized container, usual package, or individual piece
2. weight of the standard container, etc.
3. number of units of material or product in the standard container, etc.
4. total number of units of material or product required or produced for the job
5. method of stacking or storing including pallet size, if applicable
6. maximum height to stack or number of standard containers per square foot of floor space

Data on machinery must include for each piece involved:

a. its name or description

b. the floor space required for it

c. the additional floor space required for materials which may extend beyond it while in operation

d. the floor space required by the operator for safe operation of the machine

Data on work operations must include the names or description of each operation to:

a. perform processing operations

b. perform inspections

c. package and pack the product in preparation for shipping or delivery

For each of the above operations the amount of required floor space must be noted unless already covered under machinery.

Data on the quantity of output must include the following data for each work operation listed above:

a. hourly or daily production schedule which will meet the required delivery date,

b. expected output from a non-handicapped worker in competitive industry, and

c. the estimated productivity of each client to be assigned to the job for the work operation he will perform, or

d. the expected actual output of the clients assigned to the job for the work operation they will perform

A variety of material handling methods are suggested in Section 6A.

The production schedule establishes the estimated start and completion dates for each work operation. So far as possible, it permits each work operation to continue uninterrupted until the entire job is finished.

Information and forms related to a job of wrapping and packaging candles are shown on the next few pages. What material handling methods would you use and how much warehouse and production floor space will be required? Assume that all the materials for the job are received at the same time. Also, that the finished product will be shipped or delivered to the customer in from one to three lots, depending on the workshop's preference.

MATERIAL HANDLING REQUIREMENTS

1,000 Doz

Job No. 118 Item No. Item Name Candles Quantity 12,000 EA unit

Customer Brighten Up, Inc P.O. No. Contact customer workshop

Start 1/17 Finish 2/1 Phone

Total Q	Unit		Material Name/Date to Arrive or Ship	Standard Pack			No. of Std Packs	How Store	Stack High Low	Floor Space Req'd	How Move
				Units Per	Weight	Dimensions LxWxH					
12,000	EA	1	Candles	144	37	12" x 12" x 12"	84				
12,000	EA	2	Cello	500	3	3" x 13" x 2"	24				
15,000	EA	3	Label	5000	-	(Roll Form) 3/4" x 8"	3				
1,000	EA	4	Boxes	100	48	9" x 20" x 11"	10				
1,000	EA	5	Liner Paper	500	—	4½" x 12" x 2½"	2				
100	EA	6	Cartons	25	60	24" x 24" x 10"	4				
		7									
		8									
		9									
		10									

PRODUCTION ORDER

Job No. 118 Item No. ______ Item Name CANdLES Quantity 1,000 12,000 002 EA unit

Customer BRIGHTEN Up, Inc. P.O. No. ______ Contact ______ customer ______ workshop

Start 1/17 schedule ______ actual Finish 2/1 schedule ______ actual Phone ______

Description 10" tapered candles wrapped in cellophane w/pressure sensitive Label attached to wick + packed in boxes of 12 w/paper between Layers + 12 boxes packed per carton

Defects (by operation no.) ______

MATERIALS					PRODUCTION				PAY	INSPECTION		
By	Q	Unit	No/ Name	Std Pack	No.	Operation	Std Prod /Hour or Std Hrs.	Unit	Piece Rate/ Hourly Rate	Batch Size	Sample Size	AC/ RE
	12000	EA	CandLE	144	1	WRAP	100	EA				
	12000	EA	CELLO	500	2	Label	250	EA				
	15000	EA	Label	5000	3	Assemble Box	50	EA				
	1000	EA	Boxes (top+bottom)	100	4	Pack Boxes (12's)	160	EA				
	1000	EA	LINER PAPER	500	5	Set up Cartons	1.5	HR				
	100	EA	Carton	25	6							
					7							
					8							
					9							
					10							
						End Item						
				144	6	Pkg & Pack.	3.0	HRS				

Equipment & Tool List -- Work Station Arrangement on Reverse

Present
Improved Method
[✓ Proposed]

PRODUCTION STANDARDS & ESTIMATES

Date 1/10

By GWL

Sheet 1 of 1

Item CANDLES

10" size cellophane wrapped, labeled, packed 12's → 144's

Based Upon Simulated time study

			OPERATIONS						
			WRAP	Label	Assemble Box	Pack Box	Set up Cartons	Pack Carton	
PRODUCTION	q	Quantity Produced	12,000	12,000	1,000	1,000	84	84	
		Unit	EA Candle	EA Candle	EA Box	EA Box	EA Ctn	EA Ctn	
		Req'd No. of Days Q/o	7	11+	8	2	1/4	1/2	
	o	Daily Output h·w·p	1800	1050	150	630	360	180	
	h	Hrs. Worked/Day	6	6	6	6	6	6	
	w	No. of Workers	4	1+	1	1	1	1	
	p	Hourly Production 60/m or 3600/s	75	175	25	105	60	30	
STANDARDS	m s	Minutes Actual Time Seconds	m s	m s	m s	m s	m s	m s	m s
	r	Rating %	75	70	50	67	100	100	
	n	Normal Time (r·m)/100 or (r·s)/100							
	a	Allowances %							
	t	Standard Time N=(n a)/100							
	p	Hourly Production 60/t or 3600/t	100	250	50	160	—	—	
	d	Shop Rate $/Hr.							
		Labor Cost/unit d/p							

29

PRODUCTION SCHEDULE

1/17
schedule

actual
START

Job No. ______ Item No. ______

Item Name CANDLES Qty 1000 doz
unit

2/1
schedule

actual
FINISH

Total Q		12,000		12,000		1,000		1,000			
Item		Candles		Candles		Boxes (12's)		Boxes (12's)			
Q/hr		75/300		175		25		105			
Operation		WRAP (4)		LABEL		ASSEMBLE BOX		PACK BOX			
Date		goal	actual	goal	actual	goal	actual	goal	actual	goal	actual
JAN 17 M	D	900		300							
	C	900		300							
18 T	D	1200		800							
	C	2100		1100							
19 W	D	1500		900							
	C	3600		2000							
20 T	D	1800		1050		100					
	C	5400		3050		100					
21 F	D	1800		1050		125		200			
	C	7200		4100		225		200			
22 S	D	–		1050							
	C			5150							
24 M	D	1800		1050		125					
	C	9000		6200		350					
25 T	D	1800		1050		125					
	C	10800		7250		475					
26 W	D	1200		1050		125		400			
	C	12000		8300		600		600			
27 T	D			1050		125					
	C			9350		725					
28 F	D			1050		125					
	C			10400		850					
29 S	D			1600		150		400			
	C			12000		1000		1000			

7. HOW CAN YOU MAKE AND USE A PROCESS CHART?

The process chart is the most widely used work simplification form. It is prepared after the flow diagram has determined the material handling pattern and work station locations. The process chart's wide usage is a result of its ability to describe the work of a person on his job (man process chart), the changes in an item as it goes through manufacturing (material process chart), or the processing of a piece of paper or a form through a clerical routine (form process chart), to mention a few.

Symbols and definitions have been developed for use on process charts. These include:

◍ A "doing" operation: when an object is changed physically or chemically, or is assembled or disassembled.

○ A "made ready" or "put away" operation: when an object is arranged or prepared for another operation, inspection, storage, or transportation.

⇨ A transportation: when an object is moved except when the move is a part of an operation or is made by a worker at his work station.

□ An inspection: when an object is examined for identification or checked for quality or quantity.

D A delay: when conditions do not permit or require immediate performance of the next operation or inspection or storage.

▽ A storage: when an object is kept and protected against unauthorized removal.

The steps in the preparation of a process chart includes:

1. Identify the area or problem which is to be studied.
2. Choose the subject to be followed: a person, a material, a product, or a form.
3. Determine and describe the starting and stopping point in the manufacturing or processing process.
4. Write a brief description of each step--avoid the use of "and" to keep from combining two steps. Use action verbs in each phrase.
5. Assign a symbol to each step.
6. Record the time taken and distance travelled, if applicable.
7. Record the quantity produced, if applicable.
8. Note where problems exist and jot down brief ideas for improvements.
9. Summarize the operations, moves, inspections, storages, and delays.
10. Consult with employees before preparing the final chart.

The movie, THE FLOW PROCESS CHART AND HOW TO USE IT, may be rented for $9.00 for three days from the Audiovisual Center, the University of Iowa, Iowa City, Iowa, 52240.

It is an Army training film showing the steps in making flow process charts for present and improved operations. The last part of the film shows an animated Private Wilbur Brown who uses process charts to analyze and speed up his shaving so he can overcome being late for inspection.

A material process chart on the packaging of instant coffee as depicted in the flow diagram in Section 6 is shown on the next page.

The following questions seem appropriate when the flow diagram and process chart are examined:

1. Could the bag opening be eliminated as a separate operation and be done as a part of the packaging operation?
2. Why is the bag opening (step 3) so far from the bag storage and packaging area?
3. Should the sealed cartons be stored closer to the shipping area to eliminate the backtracking to the door to the aisle?
4. Could an opening be made in the wall near the sealed carton storage to allow the easy movement of sealed cartons toward the shipping area?

[✓ Present]
Improved Method

Material PROCESS CHART

Date 9/16
By JWC
Chart # Flow Diagram
Sheet 1 of 1

Subject INSTANT Coffee Packaging
4oz/Foil Envelope --- 24 Envelopes/ctn
Point of Origin Printing of envelope
End Point Sealed carton in storage

Dist in ft	Time in Min/Sec	Symbol	Description	Remarks
		①	1. Bag Printed	
24		→	2. Moves to table	
		②	3. Bag Opened	Needs improved method
		D	4. Open Bags Stored in Boxes	Cleanliness?
38		→	5. Moved to packaging Room	
		D	6. Stored on Shelves	
6		→	7. Bulk Coffee Moved to Packaging table	
		③	8. Packaged	
		④	9. Carton Sealed	
12		→	10. Carton Moved to Storage	
		▽	11. Sealed Carton in Storage	

SUMMARY	Present Method		Improved Method		Difference Saved	
	Number	Time	Number	Time	Number	Time
○ Operations	4					
→ Transportations	4					
Feet Traveled	80	☒		☒		☒
☐ Inspections	—					
D Delays	2					
▽ Storages	1					

ELIMINATE COMBINE SIMPLIFY REARRANGE SUBDIVIDE

7A. HOW CAN YOU STUDY THE MAKING OF A PRODUCT WITH A MATERIALS PROCESS CHART?

The movie, COFFEE PACKAGING, may be rented for $3.00 per showing from the University of San Francisco, Rehabilitation Workshop Administration, 2130 Fulton Street, San Francisco, California 94117. It is an 8mm silent film which shows an actual packaging operation of instant coffee in a workshop which serves a large number of clients who have suffered strokes and have good use of only one arm or leg. The job requires that 4 ozs. of the coffee is sealed in a foil lined paper bag. Allowed weight tolerance is plus about 3-4 grams, minus no grams. Twenty-four packages are packed in the shipping carton. Two densities of coffee are packaged: one weighing 80 pounds per bag and the other 55 pounds per bag. When in bulk, the coffee can be packed or loose, affecting its density considerably.

After viewing several sequences of the movie on coffee packaging, you should make a materials process chart for the job. This chart should be limited to each operation, transportation, inspection and delay through which the coffee goes until it is in its final form. Use the blank chart on page 29 for your chart. The point of origin on the chart will be the storage of the bulk bags of coffee eight feet from the table, even though this is not shown in the film. Hence, the first two lines on the materials process chart will be:

▽ 1. In bulk bags

8' → 2. Bag moved to packaging table

Note that the descriptions are written as though you, the writer, are the coffee and you are describing what happens to you. Other materials such as the foil lined bag and the corrugated shipping are treated as though they are the coffee, too, as the coffee is put in them.

Now, go on and complete the chart ending with:

▽ In carton ready for shipping

When you have finished the chart, compare it with the completed chart that follows. Do not expect them to agree exactly, but be sure you have not omitted any important steps.

You are wrong if you have included any steps on your chart which describe things done by one of the men but not involving the coffee.

As an example, the empty cup moved by the weigher back to the dipper is necessary but is not done to the coffee. Remember, the material process chart should only describe what happens to the coffee.

Count the number of operations, transportations, inspections, delays, and storages. Record them in the summary box at the bottom of the form.

Present
Improved Method

PROCESS CHART

Date__________ Subject____________________
By__________
Chart #__________ Point of Origin____________________
Sheet ____ of ____ End Point____________________

Dist in ft	Time in Min/Sec	Symbol	Description	Remarks

SUMMARY	Present Method		Improved Method		Difference Saved	
	Number	Time	Number	Time	Number	Time
○ Operations						
→ Transportations						
Feet Traveled		╳		╳		╳
□ Inspections						
D Delays						
▽ Storages						

ELIMINATE COMBINE SIMPLIFY REARRANGE SUBDIVIDE

[✓ Present] Method
Improved

Material PROCESS CHART

Date 9/20
By JWC
Chart # 2
Sheet 1 of 1

Subject INSTANT COFFEE PACKAGING
4oz / Foil Envelope 24 envelopes / CTN
Point of Origin
End Point

Dist in ft	Time in Min/Sec	Symbol	Description	Remarks
		▽	1. IN BULK BAGS	
6		→	2. BAG moved to PACKAGING table	
		○	3. BAG Opened	
		①	4. Put into Cup	LEVEL MEASURE
		D	5. Waits for Weighing	
		☐2	6. Checked on BALANCE SCALE	ELiminate
		D	7. Waits for Dumping	
		③	8. Put into BAG	
		④	9. SEALed in BAG	Automatic OR Rotary SEALER
		☐⑤	10. BAG Put into CARton	Combine with 9
		⑥	11. CARton SEALed	
12		→	12. CARton moved to STORAGE	MOVE CLOSER
		▽	13. SEALed CARton in STORAGE (READY for Shipping)	

SUMMARY	Present Method		Improved Method		Difference Saved	
	Number	Time	Number	Time	Number	Time
○ Operations	6					
→ Transportations	2					
Feet Traveled	18					
☐ Inspections	2					
D Delays	2					
▽ Storages	2					

ELIMINATE COMBINE SIMPLIFY REARRANGE SUBDIVIDE

7B. HOW CAN A MAN PROCESS CHART HELP YOU STUDY A JOB?

Now you can look at the same COFFEE PACKAGING film again to make a man process chart for the same job. This time you will concentrate on each major action of the men on the job. All the men can be shown on the same chart, in order as their actions occur. If the individual tasks were of greater importance or required more time to complete, a separate chart could be made for each man.

The point of origin will be the opened bag of bulk coffee, and the end point the sealed carton (of 24 envelopes) in storage.

The steps on this man process chart will only describe those things which the men do. This is in contrast with the material process chart which covered what happened to the coffee.

When you have completed your chart, compare it with the ones on pages 35, 36, 37, 38, and 39. The chart on pages 35 and 36 shows less detail than the one on pages 37, 38, and 39. Both are correct. Your chart should have at least as much detail as on the first chart and no more detail than the second one to be useful as a process chart. Greater detail would make it like the work simplification tool called an operation chart.

Present
Improved Method

PROCESS CHART

Date__________ Subject__________

By__________

Chart #__________ Point of Origin__________

Sheet ____ of ____ End Point__________

Dist in ft	Time in Min/Sec	Symbol	Description	Remarks

SUMMARY	Present Method		Improved Method		Difference Saved	
	Number	Time	Number	Time	Number	Time
○ Operations						
→ Transportations						
Feet Traveled		☒		☒		☒
☐ Inspections						
D Delays						
▽ Storages						

ELIMINATE COMBINE SIMPLIFY REARRANGE SUBDIVIDE

Present
Improved Method

PROCESS CHART

Date__________ Subject________________________

By__________ ________________________

Chart #__________ Point of Origin____________________

Sheet ____ of ____ End Point____________________

Dist in ft	Time in Min/Sec	Symbol	Description	Remarks

SUMMARY	Present Method		Improved Method		Difference Saved	
	Number	Time	Number	Time	Number	Time
○ Operations						
→ Transportations						
Feet Traveled						
☐ Inspections						
D Delays						
▽ Storages						

ELIMINATE COMBINE SIMPLIFY REARRANGE SUBDIVIDE

Present
Improved Method

PROCESS CHART

Date__________ Subject__________

By__________

Chart #__________ Point of Origin__________

Sheet ____ of ____ End Point__________

Dist in ft	Time in Min/Sec	Symbol	Description	Remarks

SUMMARY	Present Method		Improved Method		Difference Saved	
	Number	Time	Number	Time	Number	Time
○ Operations						
→ Transportations						
Feet Traveled		☒		☒		☒
☐ Inspections						
D Delays						
▽ Storages						

ELIMINATE COMBINE SIMPLIFY REARRANGE SUBDIVIDE

[✓ Present]
Improved Method

MAN PROCESS CHART

Date 9/22
By JWC
Chart # 3
Sheet 1 of 2

Subject Instant Coffee Packaging
4oz /Foil Envelope 24 Envelopes /ctn
Point of Origin Opened Bag of Bulk Coffee
End Point Sealed Carton in Storage

Dist in ft	Time in Min/Sec	Symbol	Description	Remarks
		→	DIP 1. Get Cup	
		○	2. Dip Cup into Loose Coffee	
		→	3. Put Cup by Weigher	
		→	Weigh 4. Move Cup to Scale	
		□	5. Read Scale	
		○	6. Add or Remove Coffee if required	
		→	7 Put Cup by Filler	
		→	8. Move Empty Cup to Dipper	
		→	FILL 9. Get Empty Bag	
		→	10. Get Cup with Coffee	
		○	11 Dump Coffee in Funnel	
		→	12. Move Bag to Sealer	
		→	SEAL 13. Put Bag in Sealer	
		○	14. Seal Bag	
		○	15. Flatten Bag	
		▣	PACK 16. Count Bags into Carton	

SUMMARY	Present Method		Improved Method		Difference Saved	
	Number	Time	Number	Time	Number	Time
○ Operations	7					
→ Transportations	11					
Feet Traveled		☒		☒		☒
□ Inspections	2					
D Delays	–					
▽ Storages	1					

ELIMINATE COMBINE SIMPLIFY REARRANGE SUBDIVIDE

[✓ Present]
Improved Method

MAN PROCESS CHART

Date 9/22
By JWC
Chart # 3
Sheet 2 of 2

Subject Instant Coffee Packaging
4oz/Foil Envelope 24 Envelopes/CTN
Point of Origin Opened Bag of Bulk Coffee
End Point Sealed Carton in Storage

Dist in ft	Time in Min/Sec	Symbol	Description	Remarks
		→	17. Move Carton to Sealer	
		○	SEAL 18. Seal Carton	
		→	19. Carry Carton to Storage	
		▽	20. Sealed Carton in Storage	

SUMMARY	Present Method		Improved Method		Difference Saved	
	Number	Time	Number	Time	Number	Time
○ Operations						
→ Transportations						
Feet Traveled		X		X		X
☐ Inspections						
D Delays						
▽ Storages						

ELIMINATE COMBINE SIMPLIFY REARRANGE SUBDIVIDE

[✓ Present] Improved Method

MAN PROCESS CHART

Date 9/22
By JWC
Chart # 4
Sheet 1 of 3

Subject Instant Coffee Packaging
4oz / Foil Envelope   24 envelopes / ctn
Point of Origin Opened Bag of Bulk Coffee
End Point Sealed carton in storage

Dist in ft	Time in Min/Sec	Symbol	Description	Remarks
		→	DIP 1. Reach for Cup	
		→	2. Move Cup to Bag	
		○	3. DIP CUP into Coffee	
		□	4. Check Quantity of Coffee in Cup	
		○	5. Dump out Excess Coffee	
		→	6. Move Cup to table by Weigher	
		D	WEIGH 7. Wait for Cup	
		→	8. Reach for Full Cup	
		→	9. Move Cup to Scale	
		□	10. Read Scale	
		→	11. Reach for Spoon	
		○	12. Add or Remove Coffee as Required	
		→	13. Replace Spoon	
		→	14. Move cup to table by Filler	
		→	15. Reach to Empty Cup	
		→	16. Move Empty Cup to Dipper	

SUMMARY	Present Method		Improved Method		Difference Saved	
	Number	Time	Number	Time	Number	Time
○ Operations	10					
→ Transportations	26					
Feet Traveled						
□ Inspections	3					
D Delays	3					
▽ Storages	1					

ELIMINATE   COMBINE   SIMPLIFY   REARRANGE   SUBDIVIDE

[✓ Present] Improved Method

Man **PROCESS CHART**

Date 9/22

By JWC

Chart # 4

Sheet 2 of 3

Subject Instant Coffee Packaging

Point of Origin

End Point

Dist in ft	Time in Min/Sec	Symbol	Description	Remarks
		○	17. Remove Spilled Coffee From Scale	
		D	FILL 18. Wait For Cup	
		→	19. Reach to Open Bag	
		→	20. Move Bag to Funnel	
		→	21. Reach to Cup with Coffee	
		→	22. Move Cup to Funnel	
		○	23. Dump Coffee into Funnel	
		→	24. Put empty Cup by Weigher	
		→	25. Move Bag to Rack by Sealer	
		D	SEAL 26. Wait for Bag	
		→	27. Reach for Bag	
		→	28 Move Bag to Sealer	
		○	29 Seal Bag	
		→	30. Move Bag to table	
		○	31. Flatten Bag	
		→	PACK 32. Reach to Bag	

SUMMARY	Present Method		Improved Method		Difference Saved	
	Number	Time	Number	Time	Number	Time
○ Operations						
→ Transportations						
Feet Traveled		X		X		X
☐ Inspections						
D Delays						
▽ Storages						

ELIMINATE COMBINE SIMPLIFY REARRANGE SUBDIVIDE

[✓ Present] Improved Method

MAN PROCESS CHART

Date 9/22
By JWC
Chart # 4
Sheet 3 of 3

Subject Instant Coffee Packaging
Point of Origin
End Point

Dist in ft	Time in Min/Sec	Symbol	Description	Remarks
		→	33. Move Bag to Carton	
		□	34. Count Bags into Carton (24x)	
		→	35. Move Carton to Sealer	
		→	SEAL 36. Reach to Carton	
		○	37. Close Flaps	
		→	38. Reach to tape machine (3x)	
		○	39. Pull tape machine Handle (3x)	
		→	40. Move tape to Carton (3x)	
		○	41. Seal Carton	
		→	42. Carry Carton to Storage	
		▽	43. Sealed Carton in Storage	

SUMMARY	Present Method		Improved Method		Difference Saved	
	Number	Time	Number	Time	Number	Time
○ Operations						
→ Transportations						
Feet Traveled		☒		☒		☒
□ Inspections						
D Delays						
▽ Storages						

ELIMINATE COMBINE SIMPLIFY REARRANGE SUBDIVIDE

8. HOW DO YOU USE AN OPERATION CHART OR AN OPERATIONS PROCESS CHART?

Operation charts include the left hand - right hand chart and the MTM analysis chart. Since these concentrate on each movement of the man in performing his job, they should be the last work simplification tool used to study and improve a job.

A flow diagram may eliminate part of the job. Study of process charts may result in reassignment of tasks. Only when these studies are complete and the final jobs well defined is it worthwhile to make a detailed analysis on the operation charts.

An operation chart is found on the next page. It shows a sequence of sealing the carton of 24 packages of instant coffee as shown in the film described in Section 7A. The preparation of process charts requires more training than can be provided here. The sample is included to show that when a job is important enough and will run long enough to justify the expenses, very thorough techniques of work simplification are available to analyze and improve it.

A blank MTM analysis chart is found in this section.

The operations process chart has a name like the above forms, but it is quite different. It is used to gather information about a chain of operations culminating in a product. It shows a good overall view of:

1. What operations are performed

2. The order in which they are performed

3. The points at which materials are added

Elsewhere in this section is an operations process chart for the coffee packaging as first described in Section 6.

[✓ Present] Proposed Method

OPERATION CHART

Date 9/23
By JWC
Chart #
Sheet 1 of 2
Actual Time/Cycle

Subject INSTANT COFFEE PACKAGING
Operation SEAL CARTON (TOP FLAPS) W/3 PIECES OF TA
Point of Origin FOLD FLAPS DOWN
End Point MOVE CARTON TO STACK

No	Left Hand Description	Symbol LH	Symbol RH	Right Hand Description	No
1	MOVE TO END FLAP (BOTTOM)	→	→	MOVE TO END FLAP (TOP)	1
2	FOLD END FLAP TOWARD CENTER	O	O	FOLD END FLAP TOWARD CTR	2
3	REACH TO LEFT SIDE FLAP	→	→	REACH TO RIGHT SIDE FLAP	3
4	FOLD SIDE FLAP TOWARD CENTER	O	O	FOLD SIDE FLAP TOWARD CENTER	4
5	HOLD FLAPS DOWN	D	→	REACH TO TAPE MACHINE HANDLE	5
6	✓	D	O	PULL HANDLE	6
7	✓	D	O	RELEASE HANDLE	7
8	✓	D	→	REACH TO TAPE	8
9	✓	D	O	GRASP TAPE & MOVE TO BOX	9
10	ASSIST POSITIONING TAPE	O	O	POSITION TAPE ON CARTON	10
11	RUB TAPE	O	O	RUB TAPE	11
12	REACH TO HANDLE OF TAPE MACHINE	→	D	IDLE	12
13	PULL HANDLE	O	D	✓	13
14	RELEASE HANDLE	O	D	✓	14
15	REACH TO TAPE	→	D	✓	15
16	GRASP TAPE & MOVE TO CARTON	O	D	✓	16
17	POSITION TAPE ON CARTON	O	O	ASSIST POSITIONING TAPE	17

SUMMARY		Present Method Number	Present Method Time	Improved Method Number	Improved Method Time	Difference Saved Number	Difference Saved Time
O Operations	LH						
	RH						
→ Transportations	LH						
	RH						
D Delays	LH						
	RH						
∇ Storages	LH						
	RH						

ELIMINATE COMBINE SIMPLIFY REARRANGE SUBDIVIDE

[✓ Present]
Proposed Method

OPERATION CHART

Date 9/73
By JWC
Chart #
Sheet 2 of 2
Actual Time/Cycle

Subject INSTANT COFFEE PACKAGING
Operation SEAL CARTON
Point of Origin FOLD FLAPS DOWN
End Point MOVE CARTON TO STACK

No	Left Hand Description	Symbol LH	Symbol RH	Right Hand Description	No
18	RUB TAPE	○	○	RUB TAPE	18
19	REPEAT #'s 12-18			REPEAT #'s 12-18	19
20	GRASP CARTON	○	○	GRASP CARTON	20
21	MOVE TO STACK	→	→	MOVE CARTON TO STACK	21

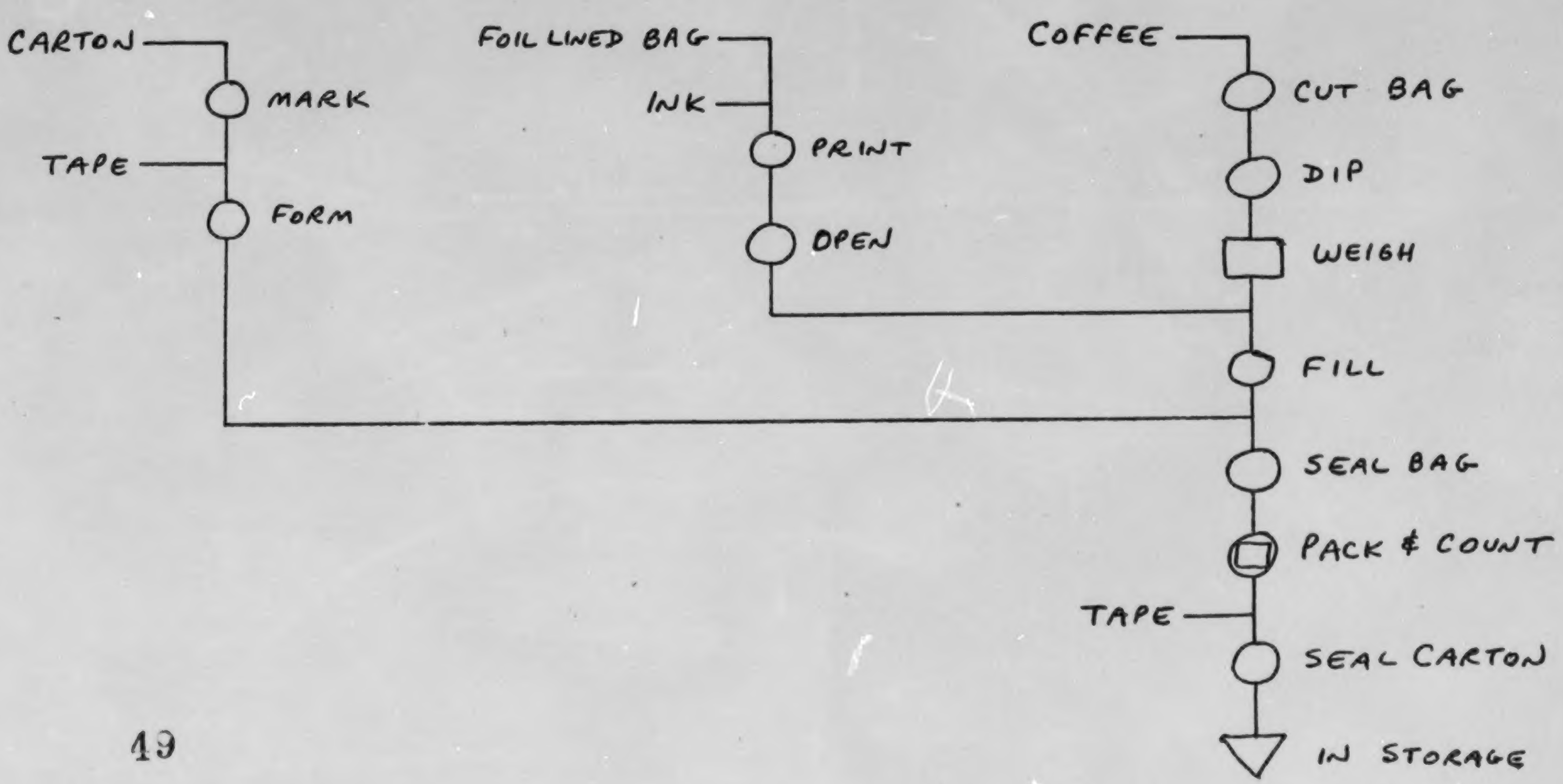
SUMMARY		Present Method Number	Present Method Time	Improved Method Number	Improved Method Time	Difference Saved Number	Difference Saved Time
○ Operations	LH						
	RH						
→ Transportations	LH						
	RH						
D Delays	LH						
	RH						
∇ Storages	LH						
	RH						

ELIMINATE COMBINE SIMPLIFY REARRANGE SUBDIVIDE

ITEM: INSTANT COFFEE PACKAGING

OPERATIONS PROCESS CHART

BY: JWC DATE: 6/8


CARTON
MARK
TAPE
FORM
FOIL LINED BAG
INK
PRINT
OPEN
COFFEE
CUT BAG
DIP
WEIGH
FILL
SEAL BAG
PACK & COUNT
TAPE
SEAL CARTON
IN STORAGE

METHODS AND TIME STANDARDS

CODE NUMBER

PART NUMBER

METHODS TIME MEASUREMENT ANALYSIS

ED. NUMBER

OPER. NUMBER

OPERATION DESCRIPTION

MATERIAL	FORM	HEAT TREAT 000 P.S.I.	VEHICLE	J.D. CARD
LOAD CENTER	DRAWING CHANGE NO.	INITIALS	DATE	START	STOP

DESCRIPTION – LEFT HAND	NO.	L.H.	TMU	R.H.	NO.	DESCRIPTION – RIGHT HAND

NO.	ELEMENT DESCRIPTION	ELEMENT TIME TMU	CONVERSION FACTOR (.00001)	% ALLOWANCE	ELEMENT TIME ALLOWED	OCCURRENCES PER PIECE OR CYCLE	STANDARD HRS. ALLOWED
1							
2							
3							
4							
						TOTAL	

9. WHAT ARE THE PRINCIPLES OF MOTION ECONOMY?

Extensive research has shown that the following principles of motion economy are applicable to all work movement:

In the general work place:

1. eliminate unnecessary and disturbing noises and distractions
2. materials and supplies should be delivered to the work place quickly and automatically, often by gravity
3. materials and supplies should be easily and automatically removed from the work place

In the individual work place:

4. correct inadequate lighting
5. eliminate hazards
6. use paint colors to reduce eye strain and to mark tools and equipment for ready identification
7. reduce large scale motions
8. use tools and equipment designed to reduce human effort
9. arrange work to permit an easy and natural rhythm

Using the simplest, smallest motions which make it possible to perform the work satisfactorily:

10. gravity feed bins and containers should be used to deliver materials close to the point of use
11. a chair of the type and height to permit a good posture should be provided. Arrange so worker can alternately sit and stand
12. two or more tools should be combined, if possible
13. motions are ranked from easiest (finger motions only) to hardest (body motions)
14. sliding materials rather than lifting and carrying them
15. momentum should be employed to assist the worker. It should be reduced to a minimum if it must be overcome by muscular effort. Arrange tools, equipment, materials, and machine controls so motion paths to them are within the range of the shortest movements of the arms.
16. perform work within reach of the hands with the elbows held close to the body
17. the hands should be relieved of all work that can be done more advantageously by a jig, fixture, or a foot operated device

Using hand and arm motions in a fixed, rhythmical sequence:

18. tools and materials are arranged to match the sequence of work steps
19. tools and materials are pre-positioned

20. the two hands should begin as well as complete their motions at the same time

21. movements follow a continuous, curved path than zigzag or straight line motions involving sudden and sharp changes in direction

22. alternate lead hand or hand used to hold tool

23. the two hands should not be idle at the same time except during rest periods

24. motions should apply power or force at the best time with the least effort

25. ballistic movements are faster, easier, and more accurate than restricted (fixation) or "controlled" movements

26. movements of the hands and arms should be in opposite and symmetrical directions and should be made simultaneously

27. hands should not be used for holding material on which an operation is being performed

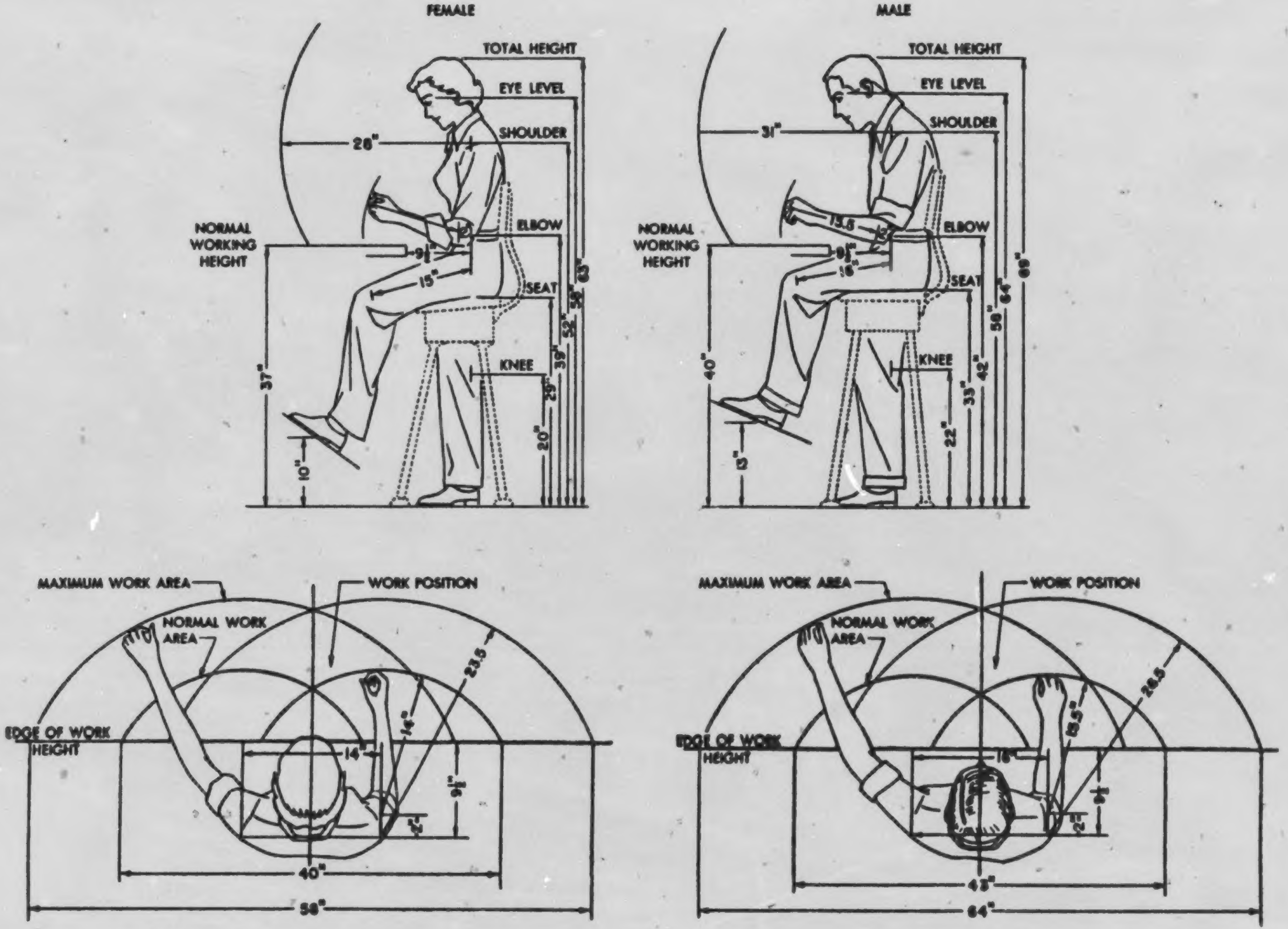
28. rhythm is essential to the smooth and automatic performance of an operation

Hence, motion economy is a way of working that requires the least effort and strain in accomplishing a job. It includes ways and means of obtaining the highest output for the least input.

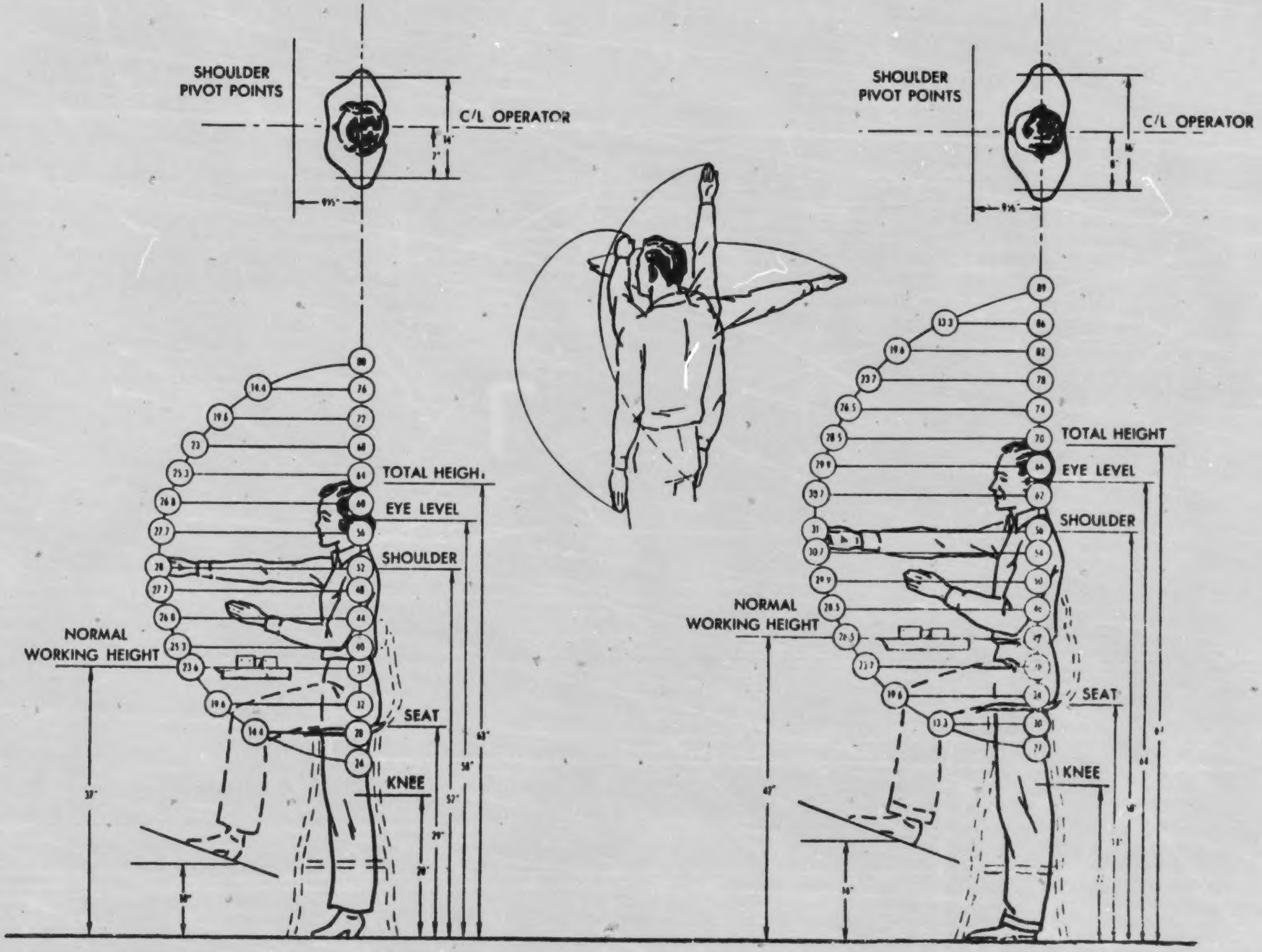
Measurements of the human body and the related reach distances which are useful in designing and constructing equipment and work place layouts are shown on the following pages.

The movie, MOTION STUDY PRINCIPLES, may be rented for $11.00 per showing from the University of California, Extension Media Center, 2223 Fulton, Berkeley, CA, 94720. (Catalog #4263)

It shows the progressive improvements made in the assembly of a bolt, lock washer, flat washer and rubber washer by using eleven principles of motion economy as developed by Ralph M. Barnes. Other applications of these principles are shown on several other hand assembly items.


FEMALE
MALE
TOTAL HEIGHT
EYE LEVEL
SHOULDER
ELBOW
SEAT
KNEE
NORMAL WORKING HEIGHT
26"
9"
15"
37"
10"
63"
58"
52"
39"
29"
20"
31"
15.5
9½"
16"
40"
13"
65"
64"
56"
42"
33"
22"
MAXIMUM WORK AREA
WORK POSITION
NORMAL WORK AREA
EDGE OF WORK HEIGHT
23.5
14"
14"
9½"
2"
40"
58"
26.5
15.5"
16"
9½"
2"
43"
64"

Average Body Measurements Used by General Motors Corporation in Designing Work


SHOULDER PIVOT POINTS
C/L OPERATOR
14"
7"
9½"
80
76
72
68
64
60
56
52
48
44
40
37
32
28
24
14.4
19.6
23
25.3
26.8
27.7
28
27.7
26.8
25.3
23.6
19.6
14.4
TOTAL HEIGH.
EYE LEVEL
SHOULDER
SEAT
KNEE
NORMAL WORKING HEIGHT
63"
58"
52"
29"
20"
37"
10"
SHOULDER PIVOT POINTS
C/L OPERATOR
16"
8"
9½"
89
86
82
78
74
70
66
62
58
54
50
46
34
30
27
13.3
19.6
23.7
26.5
28.5
29.9
30.7
31
30.7
29.9
28.5
23.7
19.6
13.3
TOTAL HEIGHT
EYE LEVEL
SHOULDER
SEAT
KNEE
NORMAL WORKING HEIGHT
41"
10"

Maximum Horizontal Reach (in Inches)
without Shift of Body Position

10. WHY SHOULD WORKSHOPS BE EFFICIENT?

The tremendous production capacity of the United States has come from the efficiency with which its resources are used. This has generated the world's highest standard of living. Business is never ceasing in the attempts to improve the productivity of its operations. Workshops must strive for the same improvements or they will fail to provide a realistic work environment for their clients.

Workshop people often have to explain that a rehabilitation program in a workshop will likely be operated at a financial loss. That is, income from the sale of workshop products and income from subcontracts will be less than the cost of making the products and doing the contract work. There are good reasons for this loss. The handicapped clients require more learning time, supervision, space and equipment, and administrative overhead than will a smaller group of non-handicapped persons producing the same quantity of products.

However, the notion that "workshops mean losses" has been misused so that wasteful and inefficient practices are sometimes explained away as the natural consequences of operating a workshop. Rehabilitation is used to cover up for managerial mistakes or low client wages or lack of concern for the cost of workshop operations. Instead of attempting to hold losses to a minimum, some workshops relax their concern for efficiency to the point of expecting or creating a loss in order to justify their existence. "After all," they say, "This is a workshop--not a business. We're concerned about people, not dollars." But sponsoring organizations and communities should no longer tolerate poor management of inefficient work practices. Nor should rehabilitation agencies accept evaluations of their clients' productivity when real work situations have not been provided.

When workshops have adopted the efficiency emphasis of business, they will find themselves financially and psychologically better off. They will also find that their rehabilitation results will improve.

The obligation to be efficient--to eliminate waste of time, of space, and of materials--is owed to many people. You, as a member of the workshop's staff owe it to:

1. Yourself

   Your own pride of workmanship can only come from knowing that you've done a good job.

2. Your Workshop

   Your salary is paid because you can return more to the workshop than it gives to you. They rely on you to work efficiently and help others to do so.

3. Your Clients

   They need your help to learn good work habits and efficient work methods. Give them less and you hurt their rehabilitation achievements.

4. Your Customers

   They may not stay your customers if someone else figures out a more efficient way of doing their work.

5. Your Community

They support your services to people programs and have a right to expect efficient use of the monies given your shop for this purpose.

Indicators of suitable Industrial Management planning and organization in a workshop:

1. Plant layout permits a minimum of material handling and movement.
2. Material handling uses efficient, laborsaving methods and equipment.
3. Work stations are comfortable with adequate light, heat and cooling, ventilation, cleanliness, furniture for proper posture and with reasonable proximity to drinking water, restrooms, eating and rest areas.
4. The amount of material required for each job is specified in advance. Use of more or less than this amount is recorded.
5. Materials come to each work station either precounted or in lots or batches of uniform size.
6. Surge piles of materials between workers performing operations in sequence permit each worker to produce at his own speed.
7. Operations to be performed on each product are described in advance and the expected standard level of output is specified if the job is to continue 3-5 days or more.
8. Workplace layout and tooling permits a minimum of movements and exertion by the worker to perform his task.
9. The quantity of satisfactory work completed and the time required is recorded for each worker. When substantial amounts of non-productive time or make-work occur, the reason is specified and the time is recorded for each worker involved.
10. The defects which can occur in the products being produced are specified in advance.
11. The first few items produced by each worker are examined for defects when he starts or resumes a job after an interruption. Periodic inspections are continued during production with defects found and the worker producing them being recorded.
12. Start up dates for jobs permit uninterrupted work assignments for workers who are permitted increasing specialization as the job lengthens.
13. Work is completed on schedule to meet reasonable customer needs.

10A. WHY IS THE METHOD OF DOING A JOB IMPORTANT?

Pegboard can be constructed and used in a live demonstration to show that the way the job is done has a greater effect on the time required than does the effort of the worker.

The 3/4" thick pegboard used has thirty 3/8" holes drilled all the way through in a 6 x 5 pattern. The holes are 1" OC with a 5/8" diameter 45 degree counter bore. The pegs are 2-3/4" long, 5/16" in diameter with one end rounded. There are at least 36 pegs available for each board.

Ask a person (preferably one who has not been exposed to motion study) to "put the pegs in the board while I time you with the stop watch." They will ordinarily use a one-handed method. If they do not, disregard the time and ask them to do it one-handed. Give the person a second or third trial, and record the times again. Be sure they use the same method (one-handed). Get one or two other people to use the same method, recording times for their three or four trials.

Then show that less time is required when one hand is used to hold a group of pins and feed them one at a time to the other active hand.

Now, ask the demonstrators to use a two-handed method with each hand picking up and inserting a pin at the same time.

Finally, show the demonstrators the best method which starts by filling the holes nearest the operator and in the center of the board. Fill up the row moving away from the operator. Then move to the next outside row with each hand, again starting with the holes nearest the operator.

It will be found that the one-handed method will take approximately twice as long as the best two-handed method.

Someone may question the validity of the improvement gains because they could at least partly be due to the increased practice as they went from one-handed to two-handed methods. The following demonstration can then be used.

Reverse the order; that is, start by teaching the two-handed, best method, to a person. Record his best time. Then ask him to use progressively poorer methods until the one-handed technique is reached. It will be found that roughly the same differences in time will be shown between methods. This should show rather conclusively that work methods greatly affect the time required to complete a job.

IOB. HOW CAN YOU IMPROVE A JOB AFTER DESCRIBING IT ON A PROCESS CHART OR OPERATION CHART?

Priorities for improving methods which have been charted on a process chart:

1. Delays are the most easily changed
2. The "make ready" and "put aways" can usually be improved
3. The "do" operations usually need the least improvement

Questioning why an operation, transportation, inspections, storage or delay occurs, is facilitated by these questions:

1. Can it be eliminated?
2. What is it supposed to do?
3. Does it do what it is supposed to do?
4. Is its purpose still a part of the job?
5. What makes the purpose necessary?
6. Does the immediate purpose serve to carry out a larger purpose?
7. What would happen if it was not done?

When improving a work method, the following steps should be taken in the order given:

1. Eliminate the work because:
   - Its purpose has long disappeared
   - It is performed for operator convenience
   - A different sequence would make it unnecessary
   - Better equipment would make it unnecessary
2. Combine the work through:
   - A change in work place or equipment design
   - A change in sequence
   - A change in raw material or end product design
   - Evidence that the work load at a certain work place is too low
   - Cross training to increase the skill of operators
3. Rearrange the sequence of work to:
   - Ease or shorten any of the work
   - Reduce material handling or walking
   - Save floor space or reduce in-process time
   - Take advantage of better equipment or skills
4. Improve the work by:
   - Pre-position materials and tools
   - Better equipment
   - Use gravity feed hoppers and drop delivery chutes
   - Let both hands do useful work
   - Use jigs and fixtures instead of hand for holding work
   - Training operators in better work patterns
   - Better services or supervision

There are eight basic hand motions or actions which are involved in most manual tasks. The following suggestions for each of them may be helpful in making improvements:

1. Select
   - Can the layout eliminate searching for items?
   - Can tools and materials be standardized?
   - Are parts and materials properly labeled?
   - Can parts and materials be pre-positioned?
   - Can color be used to facilitate selection?
   - Is lighting satisfactory?
   - Are parts and materials mixed?
   - Could bins, trays, etc., facilitate or eliminate selection?

2. Grasp

Is it possible to grasp more than one at a time?
Can objects be slid instead of carried?
Will a lip on a bin simplify grasp of small parts?
Can tools or parts be pre-positioned for easy grasp?
Can a vacuum, magnet, rubber finger, etc., be used?
Is article transferred from one hand to another?

3. Transport

Can the motion be eliminated?
Is the distance travelled necessary?
Are the proper means used: foot, hand, pliers, conveyor?
Are the lowest classification of body members used?
Can a chute or conveyor be used?
Could items be accumulated and moved in larger groups?
Is transport slowed for a close fit positioning at the end of it?
Are preceding and following operations properly related?
Can abrupt changes in motion be eliminated?
Is the fastest body member used for weight moved?
Can any body movements be eliminated?
Can arm movements be made simultaneously, symmetrically and in opposite directions?
Can the object be slid instead of carried?
Are eye movements coordinated with hand motions?

4. Hold

Can a vise, clip, vacuum, hook, rack, fixture be used?
Can adhesive or friction be used?
Can a stop be used to eliminate hold?
Could arm rests reduce fatigue?

5. Release

Can drop delivery be used?
Can the release be made in transit?
Can a careful release be eliminated?
Can an ejector be used?
Are material bins properly designed and located?
At the end or release is the hand in most advantageous position for next motion?

6. Pre-position

Can object be pre-positioned in transit?
Can the tool be balanced in usable position?
Can article be designed so as many sides are alike as possible?
Can magazine or clip feed be used?
Can a stacking device be used?
Can a rotating fixture be used?

7. Position

Can tolerances be increased?
Is positioning necessary?
Can square edges be eliminated?
Can a guide, stop, locating pin, recess, swing bracket be used?
Can arm rests steady the hands and reduce positioning time?
Has the object been grasped for easiest positioning?
Can a foot operated device be used?

Inspect

Can illumination be increased?
Can gauges be used?
Can mechanical inspection replace visual?
Can pressure, vibration or hardness test be used?

The most thorough method of analysis and action uses a process chart like the one on the next page. It has additional columns to make certain that all questions for analysis and methods of action are considered.

After all the description statements have been written for each of the steps in the job you are studying, go back to each line and:

1. Put your pencil in the "What" column and ask, "What is the purpose of this?" If the answer seems satisfactory, place a dot in the column.
2. Put your pencil in the "Where" column asking, "Where should we do this?" Again, place a dot in the column if the location seems right.
3. In the "When" column ask, "when should we do this?"
4. "Who"--"Who should do this?"
5. "How"--"How should this be done?"

Whenever a question is not satisfactorily answered, a check is put in the column instead of a dot. Ordinarily, no additional analysis questions are asked when a check is made.

6. When a check is made in the analysis column, look in the action columns for an idea suggested by one of the words, "Eliminate," "Combine," "Change Sequence," "Change Place," "Change Person," or "Improve" which will overcome the problem. Put a check in the action column which triggered your idea. If necessary, jot the idea down on the back of the sheet.

Some of the checks in the action column will conflict with others. Pick out the best ideas and discuss them with all concerned. A proposal will come out of this pooling of brainpower with the way prepared for its ultimate acceptance.

Present
Improved Method

Man
Material PROCESS CHART

Date________________ Subject________________________________
By________________ ________________________________
Chart #________________ Point of Origin________________________________
Sheet ___ of________ End Point________________________________

Dist in ft	Time in min or sec	Symbol	Description	Analysis					Action					
				Why							CHANGE			
				What	Where	When	Who	How	Eliminate	Combine	Sequence	Place	Person	Improve

SUMMARY	Present Method		Improved Method		Difference Saved	
	Number	Time	Number	Time	Number	Time
O Operations						
➔ Transportations						
Feet traveled		XXXXXX		XXXXXX		XXXXXX
□ Inspections						
D Delays						
▽ Storages						

ELIMINATE COMBINE SIMPLIFY REARRANGE SUBDIVIDE

10C. HOW CAN YOU SELECT THE BEST WORK METHOD?

It is very important, especially on jobs with high cost or high savings potential, to have several thought-out alternatives. Stopping with and developing the first idea for improvement which comes to you will fall far short of the improvements which more thought can develop.

So, have several thought-out alternatives.

Then reject those which are not presently feasible.

Compare the ones remaining in terms of:

1. Operating cost changes
    - Direct labor or direct materials cost
    - Indirect labor or supplies cost
    - Overhead cost
2. Installation Costs
    - New equipment costs
    - Salvage return from old equipment
    - Training costs
3. Other changes which affect?
    - Quality
    - Personnel
    - Safety
    - Production capacity

The form on the following page may be useful for this purpose.

DIFFERENCE-COMPARISON CHECKLIST

Operating Costs	CHANGED Yes	No	PRESENT METHOD	PROPOSED METHOD	DIFFERENCE
			Units:		
Direct Labor					
Direct Material					
Indirect Labor					
Indirect Material					
Tool Cost					
Scrap Cost					
Maintenance					
Heat,power,light					
			Yearly Volume: Annual Savings:		

Installation Costs	DESCRIPTION	
New Tools		
New Equipment		
Labor		
Material		
Salvage		
Training		

OTHER CHANGES RESULTING FROM NEW METHOD

Quantity Produced

Quality

Safety

Personnel

11. HOW CAN YOU LAY OUT A WORK PLACE OR PRODUCTION LINE?

The arrangement of the space around each client in a workshop requires consideration of the following factors:

1. Posture required by the task: sitting, standing, alternately sitting and standing, standing and walking
2. Machinery, jigs, fixtures, tools and work benches or tables which are to be used along with space requirements of each
3. Number of units of production expected per hour or day
4. Materials: size and weight to be handled, bulk and quantity in storage at work place, method of material handling, frequency of movements
5. Safety through elimination or control of hazards
6. Relationships with other workers who work on the same item

The movie, THE FOREMAN DISCOVERS MOTION STUDY, number 4609 may be rented for $18.00 per showing from the University of California, Extension Media Center, 2223 Fulton, Berkeley, CA 94720.

It shows the efforts of a group of foremen before and after their study of motion economy. The group's task is to construct a wooden box which is filled with jelly beans. The improvements which are based on motion economy principles are clearly and dramatically shown.

Four problems or case studies will be found on the next few pages. For each you will find a:

1. Materials Handling Requirements Sheet which was prepared by the Sales Department.
2. Production Order which was prepared by the Production Supervisor
3. Production Standards and Estimate Sheet which was prepared by the Engineering Department

From this data you are to:

1. Indicate the number of items in each lot, batch, or bundle or raw material, finished parts or finished items in each operational step
2. Pay particular attention to the material handling aspects, including provisions for surge piles of materials between operations
3. Design the work place layouts for the operations required in the making of this item

You may show a scale drawing of your design on graph paper or a large layout on wrapping paper or make a full sized layout using corrugated board.

PRODUCTION ORDER

Job No. 111 Item No. ______ Item Name JEEP DISPLAY Quantity 4000 EA unit

Customer AMERICAN Motors P.O. No. ______ Contact ______ customer ______ workshop

Start 4/17 schedule ______ actual Finish 5/14 schedule ______ actual Phone ______ ______

Description 2 sheets 35"x 42" plain paper, 5 different 18" x 29" Posters, 2-20"x29" Posters, and 2 each of 8 different 18"x29" Paper Flags. Roll and insert in heavy tube

Defects (by operation no.) ______

MATERIALS					PRODUCTION				PAY	INSPECTION		
By	Q	Unit	No/ Name	Std Pack	No.	Operation	Std Prod /Hour or Std Hrs.	Unit	Piece Rate/ Hourly Rate	Batch Size	Sample Size	AC/ RE
	8000 (of	EA Each)	FLAGS (8 Kinds)	500	1	Collate	25	sets				
	8000	EA	Small Posters	500	2	Roll + Package	35	tubes				
	4000 (of	EA Each)	Lg Posters (5 Kinds)	500	3							
	4000	sheets	Paper	500	4							
	4000	EA	tubes	36	5							
					6							
					7							
					8							
					9							
					10							
				36		End Item						
						Pkg & Pack.						

Equipment & Tool List -- Work Station Arrangement on Reverse

MATERIAL HANDLING REQUIREMENTS

Job No. 111 Item No. ______ Item Name JEEP DISPLAY Quantity 4000 EA unit

Customer AMERICAN MOTORS P.O. No. ______ Contact ______ customer ______ workshop

Start 4/17 Finish 5/14 Phone ______

Total Q	Unit		Material Name/Date to Arrive or Ship	Standard Pack			No. of Std Packs	How Store	Stack High Low	Floor Space Req'd	How Move
				Units Per	Weight	Dimensions LxWxH					
64,000	EA	1	FLAGS 4/15 (8 Kinds)	500		29" x 18" x 4½"					
8,000	EA	2	Sm Posters 4/15	500		29" x 20" x 4½"					
20,000	EA	3	Lg. Posters 4/15 (5 Kinds)	600		41" x 29" x 4½"					
4,000	Sheets	4	PAPER 4/15	500		42" x 35" x 5"					
4,000	EA	5	tubes 4/10	36 (tied Bundle)		43" x 29" x 29"					
		6									
		7									
		8									
		9									
4,000	EA	10	End ITEM - tuBes	36 (tied Bundle)		43" x 29" x 29"					

[✓ Present]
Improved Method
Proposed

PRODUCTION STANDARDS & ESTIMATES

Date 4/24
By B.B.
Sheet 1 of 1
Item JEEP DISPLAY
Job #111
Based Upon time Study

			OPERATIONS						
			CoLLate	RoLL + PACK					
PRODUCTION	q	Quantity Produced	4,000	4,000					
		Unit	sets	tubes					
		Req'd No. of Days Q/o							
	o	Daily Output h·w·p							
	h	Hrs. Worked/Day							
	w	No. of Workers							
	p	Hourly Production 60/m or 3600/s							
	m s	Minutes Actual Time Seconds	m 2.0 s	m 1.9 s	m s	m s	m s	m s	m s
STANDARDS	r	Rating %	100	80					
	n	Normal Time (r·m)/100 or (r·s)/100	2.0	1.5					
	a	Allowances %	120	120					
	t	Standard Time N=(n·a)/100	2.4	1.8					
	p	Hourly Production 60/t or 3600/t	25	35					
	d	Shop Rate $/Hr.							
		Labor Cost/unit d/p							

PRODUCTION ORDER

Job No. 419 Item No. ______ Item Name Curlers Quantity 200,000 EA unit

Customer Plastic Products Co P.O. No. ______ Contact ______ customer ______ workshop

Start 4/15 schedule ______ actual Finish ______ schedule ______ actual Phone ______

Description two Piece Plastic Hair Curlers Assembled together and Packaged in Bulk in a Poly Bag & Closed with a tie wire

Defects (by operation no.) ______

MATERIALS					PRODUCTION				PAY	INSPECTION		
By	Q	Unit	No/ Name	Std Pack	No.	Operation	Std Prod /Hour or Std Hrs.	Unit	Piece Rate/ Hourly Rate	Batch Size	Sample Size	AC/ RE
	200,000	EA	Base	500	1	trim	600	EA				
	200,000	EA	tube	500	2	Assemble	800	EA				
	1,400	EA	Bags	5,000	3							
	2,000	EA	tie wire	100	4							
					5							
					6							
					7							
					8							
					9							
					10							
						End Item						
					3	Pkg & Pack.	200	EA				

Equipment & Tool List -- Work Station Arrangement on Reverse

MATERIAL HANDLING REQUIREMENTS

Job No. 419 Item No. _____ Item Name Curlers Quantity 200,000 EA unit

Customer Plastic Products Co P.O. No. _____ Contact _____ customer _____ workshop

Start 4/15 Finish _____ Phone _____

Total Q	Unit		Material Name/Date to Arrive or Ship	Standard Pack			No. of Std Packs	How Store	Stack High Low	Floor Space Req'd	How Move
				Units Per	Weight	Dimensions LxWxH					
200,000	EA	1	BASE	500		24" x 14" x 20"					
200,000	EA	2	tuBE	500		24" x 14" x 20"					
1,400	EA	3	BAGS	5,000		18" x 18" x 12"					
2,000	EA	4	tie Wire	100		6" x 1" x 1"					
		5									
		6									
		7	Shipping Carton — Save + Reuse Cartons								
		8	in which Bases and tubes were received								
		9									
		10									

Present
Improved Method
Proposed

PRODUCTION STANDARDS & ESTIMATES

Date 4/3
Item Curlers
By JWS
Job # 419
Sheet 1 of 1
Based Upon Customer's Data

			OPERATIONS						
			tRIM	Assemble	PACKAGE				
PRODUCTION	q	Quantity Produced	200,000	200,000	1,400				
		Unit	BASE EA	EA	BAGS				
		Req'd No. of Days Q/o							
	o	Daily Output h·w·p							
	h	Hrs. Worked/Day							
	w	No. of Workers							
	p	Hourly Production 60/m or 3600/s	200	400	160				
	m s	Minutes Actual Time Seconds	m s	m s	m s	m s	m s	m s	m s
STANDARDS	r	Rating %	33	50	80				
	n	Normal Time (r·m)/100 or (r·s)/100							
	a	Allowances %							
	t	Standard Time N=(n·a)/100							
	p	Hourly Production 60/t or 3600/t	600	800	200				
	d	Shop Rate $/Hr.							
		Labor Cost/unit d/p							

PRODUCTION ORDER

Job No. 101 Item No. ____ Item Name Gift WRAP Quantity 4,800 tubes unit

Customer Look Good Co. P.O. No. ____ Contact ____ customer ____ workshop

Start 12/20 schedule ____ actual Finish 12/22 schedule ____ actual Phone ____

Description 108" of 30" wide wrapping paper Rolled on a Cardboard tube + Cello wrapped + heat sealed along entire Length w/ends tucked in (Paper 1833 Ft/Roll)

Defects (by operation no.) ____

MATERIALS					PRODUCTION				PAY	INSPECTION		
By	Q	Unit	No/ Name	Std Pack	No.	Operation	Std Prod /Hour or Std Hrs.	Unit	Piece Rate/ Hourly Rate	Batch Size	Sample Size	AC/ RE
	52	Rolls	PAPER	1	1	Set up Cartons	2.0	HRS				
	4800	EA	tubes	91	2	Cut PAPER	180	EA				
	4800	EA	Labels	2000	3	Roll + SEAL	40	EA				
	5000	EA	CELLO-PHANE	500 + 5000	4							
	200	EA	Carton	25	5							
					6							
					7							
					8							
					9							
					10							
						End Item						
		tubes		24	4	Pkg & Pack.	3.5	HRS				

Equipment & Tool List -- Work Station Arrangement on Reverse

MATERIAL HANDLING REQUIREMENTS

Job No. 101 Item No. ______ Item Name Gift WRAP Quantity 4,800 tubes unit

Customer LOOK Good Co P.O. No. ______ Contact ______ customer ______ workshop

Start 12/20 Finish 12/22 Phone ______

Total Q	Unit		Material Name/Date to Arrive or Ship	Standard Pack			No. of Std Packs	How Store	Stack High Low	Floor Space Req'd	How Move
				Units Per	Weight	Dimensions LxWxH					
52	Rolls	1	PAPER	1	60	8" dia x 30"					
4,800	EA	2	tubes	91		13" x 15" x 30"					
4,800	EA	3	Labels	3000		6½" x 4½" x 4"					
5,000	EA	4	Cellophane	500 + 5,000		5000's 34" x 6" x 10"					
200	EA	5	Cartons	25		16" x 37" x 10"					
200	Ctns	6	End ITEMS	24		31" x 9½" x 6¾"					
		7									
		8									
		9									
		10									

PRODUCTION ORDER

Job No. 106 Item No. ______ Item Name Switch Blocks Quantity 20,000 EA unit

Customer SPARKLE Light Co P.O. No. ______ Contact ______ customer ______ workshop

Start 8/10 schedule ______ actual Finish 8/24 schedule ______ actual Phone ______

Description INSERT 12 Pins in PLASTIC BLOCK & CRIMPENDS with AIR cylinder FIXTURE. Ship in BULK CARTONS AS AVAILABLE

Defects (by operation no.) ______

MATERIALS					PRODUCTION				PAY	INSPECTION		
By	Q	Unit	No/ Name	Std Pack	No.	Operation	Std Prod /Hour or Std Hrs.	Unit	Piece Rate/ Hourly Rate	Batch Size	Sample Size	AC/ RE
	20,000	EA	BLOCKS	300	1	INSERT PINS	75	EA				
	240,000	EA	PINS	20,000	2	CRIMP	200	EA				
					3							
					4							
					5							
					6							
					7							
					8							
					9							
					10							
						End Item						
				BULK		Pkg & Pack.						

Equipment & Tool List -- Work Station Arrangement on Reverse

12. WHAT IS WORK MEASUREMENT?

Work measurement is the systematic determination of how long it should take an average operator, in a given situation, to do a specified task.

The result of work measurement is a production standard. It can be stated in several ways, including:

1. Pieces Per Hour

   The number of pieces or items or operations which should be completed or performed per hour or per day.

2. Standard Hours

   The amount of time allowed per piece or per operation.

3. Piece Rate

   A piece rate which is calculated by dividing the number of pieces or operations per hour (as in #1) into the going hourly labor rate (the amount paid in competitive employment for a similar kind of work).

The most fundamental production standard is the pieces per hour. It can be used to calculate standard hours. It must be used to calculate a piece rate.

Before work measurement is done, it is assumed that work simplification has been applied to select the best method of doing the job.

12A. HOW DO YOU MEASURE WORK?

1. Using past performance records

   This can penalize workers who have been working above normal pace or benefit slow workers, depending on the relative numbers of each in the group or sample. Past performance means little unless you know the pace at which the work was performed. Furthermore, linking anticipated production to past performance fixes all of the inefficiencies, delays, and output restrictions of the past into a normal and acceptable performance.

2. The supervisor's estimate of how long a job should take

   Ultimately such estimates are based on past performance knowledge of the job, or similar jobs. All the weaknesses of past performance standards thus continue in supervisor's estimates

3. Time study and pre-determined time

   Pre-determined time is grouped with time study since it, too, was based on the use of a stop watch when the times were determined. Ultimately, these systems of work measurement depend on the identification and timing of work elements and an evaluation of the times observed with respect to some concept of normal pace.

4. Work sampling

   This is a statistical method of making a large number of observations of a worker over a period of time to determine the percentage of time being spent on various tasks and/or idle

5. Customer's opinion

   Beware unless you know the customer is telling you how many pieces he gets from his average employees for the entire day. He may be telling you how much his engineers say he should get or how much he would like to be getting.

6. Union's opinion

   This may become a more important source of production standards as time goes on.

13. WHAT IS A QUICK WAY TO SET A PRODUCTION STANDARD?

Unless more detailed methods are described (such as those described in Sections 14 and 15), piece rates and/or expected pieces per hour can be determined for most workshop jobs by using the following steps.

1. Time at least 2, but preferably 3 or more, non-handicapped people doing the job.
2. Calculate the average time taken to make one item or do one operation.
3. Divide the average time into the number of minutes a worker should be able to work out of each hour to find the number of pieces per hour an average non-handicapped person would be expected to produce.
4. Divide the expected pieces per hour into the hourly rate of pay which would be paid in your community for this kind of work to obtain the piece rate of labor cost.

A form for these steps is found on the next page.

Before beginning these steps (or starting any time study or work measurement system), be sure you have developed the work method which should be used by the worker. It should be the best method available considering the size of the job, equipment, etc. Jobs involving a large number of people or many hours of work will ordinarily be planned more carefully than short, non-recurring jobs. All of the techniques previously described will be helpful in selecting this best method. If unnecessary or poor work methods are being used, the piece rates and expected pieces per hour which result will be erroneous.

More detailed explanation of the four steps follows:

1. Timing

The work is to be performed by people who are non-handicapped. In addition, they should be familiar with the job to be performed through previous experience or a practice period.

If the job has not previously been done by each person, a number of practice items should be made or assembled before starting to time the work. More items should be practiced on when the length of time required for one item increased due to its being a more difficult item. If the time for one item is long merely because the work consists of a larger number of simple steps, then a longer practice period can be disregarded. The following table is suggested to indicate the amount of practice which should be provided when no previous experience is possessed by a person who is to be timed.

Approx. length of time to do one item or operation (assuming that longer times are due to greater difficulty)	Minimum number of items or operations to be made in a practice session before timing starts
Less than 1 minute	20
1 minute to 2 minutes	25
2 minutes to 4 minutes	30
4 minutes to 8 minutes	35
More than 8 minutes	40

WORK TIME
and
EXPECTED HOURLY OUTPUT

Job No.________________ Item No.______________ Item Name__________________________ Date____________

Worker/Task	TIME (Min:Sec)										
	1st Trial		2nd Trial		3rd Trial		4th Trial		Totals		$\frac{E}{F}$
	(min/sec) Time (A)	Items (M)	(min/sec) Time (B)	Items (N)	(min/sec) Time (C)	Items (P)	(min/sec) Time (D)	Items (Q)	(A+B+C+D) Time (E)	(M+N+P+Q) Items (F)	Avg Time (G)
1											
2											
3											
4											
5											

Worker/Task	$\frac{E}{F}$ Average Time (G)	(min/sec) work time per hour (H)	$\frac{H}{G}$ Pieces/Hour (J)	(Dollars) Industrial Pay Rate Per Hour (K)	$\frac{K}{J}$ Piece Rate (L)
1					
2					
3					
4					
5					

Arrange the work place exactly as it will be set up for the ultimate worker with tools, materials, work space, seating, etc., in place. Have jobs or fixtures built and equipment set up with the "bugs" worked out by previous testing and use. Do not experiment during the timing period, since this should have been done already.

An ordinary watch, preferably one with a sweep second hand can be used to record the time. If possible, permit the person who is performing the test to do several items without stopping between them. Time for the entire period he or she worked. Deduct time for interruptions which were not required by the work itself such as stopping for personal needs, etc.

2. Calculate Average Time

Determine the total time taken by each person for the actual work he did in the test. Divide this time by the number of items or operations he completed to get his average time per piece or operation. If several people participated in the test, calculate the average time for each one separately. If the average time for one of the people in the test is either less than half as long as the slowest person or more than twice as long as the fastest person, with the other people's average times within 25 - 30% of each other, it is best to disregard the extremely fast or slow individual and omit his times from the following calculations. Add the acceptable individual average times and divide by the number of people in the test to get the group's average time per item or operation.

Example:

The workshop is preparing a bid on making a plastic toy. First, it is to be assembled and glued. After assembly, it is packaged in a display box which is then packed in a shipping carton.

When various assembly and gluing work methods were tested out, one was finally selected. It took about 3 minutes to make the first toy using the selected method. The packaging and packing took just under one minute.

The preceding table was used to determine how much practice should be allowed the three supervisors who were going to be timed in the test since none of them had done this kind of work before. From the 3 minute time for making the first toy, the table indicates that 30 toys should be assembled in the practice session before timing would start. Components for 90 toys were given the supervisors and they each assembled 30 of them for practice. The practice session lasted just about one hour, for they found the time required for each toy dropped steadily as they become more experienced.

Each of the three supervisors was then given parts for 10 more toys to be assembled in the timed session. The actual time taken by each was:

	Started	Stopped	Total Time (min/sec)
Supv #1	3:30 p.m.	3:51	21/00
Supv #2	3:30 p.m.	4:01 & 15 sec.	31/15
Supv #3	3:30 p.m.	3:47 & 20 sec.	17/20

Since the times varied widely, a second trial of 5 toys was run.

	Started	Stopped	Total Time (min/sec)
Supv #1	4:10 p.m.	4:20 & 45 sec.	10/45
Supv #2	4:10 p.m.	4:24	14/00
Supv #3	4:10 p.m.	4:19 & 10 sec.	9/10

The times for each supervisor were then averaged:

	Total Time Min/Sec	Sec.	Toys Made	Avg Time Per Toy (sec)
Supv #1	21/00 + 10/45 =	1905	15	127
Supv #2	31/15 + 14/00 =	2715	15	181
Supv #3	17/20 + 9/10 =	1590	15	106

And the average of the group becomes:

	Average Time (seconds)
Supv #1	127
#2	181
#3	106
Divide by	3)414 seconds
Group Average	138 seconds per toy for assembly and gluing

For packaging practice, each supervisor was given 20 toys, since the time required was thought to be under one minute for each toy.

Each supervisor was then timed while packaging 20 toys with the following results:

Supervisor:	#1	#2	#3
Started	8:35 a.m.	8:35 a.m.	8:40 a.m.
Stopped	8:48 & 10 sec.	8:50	8:52 & 45 sec.
Total Time (min/sec)	13/10	15/00	12/45
Total Time (seconds)	790	900	765
Toys Packaged	20	20	20
Avg Time/Toy	40	45	39

Their group average was:

#1 40
#2 45
#3 39

3 124
42 seconds per toy packaged

Hence, the average time was found to be:

Assembly: 138 seconds
Packaging: 42 seconds

3. Pieces Per Hour

A worker spends only a part of each hour he is on the job actually performing work.

Some part of each hour is spent caring for his personal needs (getting a drink, smoking, talking with co-workers about sports or family or news, toilet needs, short rest periods, coffee breaks, etc.)

An additional part of each hour may be used simply for waiting rather than working. The worker is personally ready and willing to work, but he is forced to wait for materials, wait for instructions or inspection approvals, wait for a machine to be repaired or adjusted, or for some other job caused delay.

The 50 minute hour has been proposed and widely used in industry to indicate that 10 minutes out of each hour is being set aside for the personal needs or job delays described above. For most workshops, however, this 50 minute hour is unrealistic. Workshops are not that well managed. (Nor, for that matter, are many profit-seeking businesses). Hence, the use of a 45-minute hour (2700 seconds) is suggested unless you can demonstrate that the management of your workshop is so efficient that clients really have an opportunity to work some greater portion of the hour. In some workshops where the foreman-supervisor to client ratio is quite high (1 to 15 or 20 or more) a 40 minute hour might be even more realistic. In no case should a workshop go beyond the 50 minute figure, however, for this represents the ideal used by large companies with good working conditions.

The time value found in Step 2 is divided into the number of minutes (or seconds) you select for the expected working time per hour in your shop. The result is the number of items or operations you would expect from a fully productive, non-handicapped worker for each hour he spends on the job.

This pieces per hour is one way a production standard can be expressed.

Example:

In the previous example for Steps 1 and 2, the average time per toy was found to be 138 seconds for assembly and 42 seconds for packaging.

If the shop used the 45 minute hour (2700 seconds), the number of toys expected to be assembled per hour are:

$$\frac{\text{Working Sec/Hour}}{\text{Sec for 1 Assembly}} = \text{Pieces/Hour}$$

$$\frac{\text{2700 seconds}}{\text{138 seconds}} = 19\tfrac{1}{2} \text{ toys assembled/hour}$$

The expected packaging per hour would be:

$$\frac{\text{2700 seconds}}{\text{42 seconds}} = \text{64 toys packaged/hour}$$

4. Piece Rates

In order to determine the fair wage to be paid clients for their work, you must know the average wage paid to employees in local companies doing a similar kind and level of work. A problem arises as you try to find "similar" work, for a variety of factors go to make up the content of a job.

To match up the workshop job with one from competitive employment, you disregard the amount of work done in the competitive job but compare:

a) What are the relationships with data which is observed or mentally created including numbers, words and symbols?

    1) Analyzing
    2) Compiling
    3) Computing
    4) Copying
    5) Comparing

b) What are the relationships which lead to various interpersonal relationships including instructing, supervising, persuading, speaking and serving?

c) What are the relationships with things such as materials, machines and products?

   1) Precision Working
   2) Operating-Controlling
   3) Manipulating-Tending
   4) Handling

d) How much flexibility is expected to be able to do different kinds of work or a sequence of tasks?

e) What quality of work is performed as judged by the degree of perfection required (amount of errors or flaws permitted without being classified as a reject) or number of rejects allowed?

f) How much supervision is provided, what kind of people are the supervisors?

g) Is the job seasonal, intermitten or temporary?

It is seldom possible to exactly match a workshop job with a job from competitive employment using all of the above comparisons. Generally, the competitive job will be more demanding than the workshop job. As a result, the rate of pay in competitive employment should not be the rate to be used by the workshop in determining its piece rate, unless the workshop wishes to provide a wage subsidy to its clients.

In selecting a wage rate, the workshop should apply the same test which the Department of Labor's Wage and Hour Division is directed to enforce by the Fair Labor Standards Act and the related Regulations. This requires that: 1) a wage be paid to handicapped workers (clients) commensurate with that paid to non-handicapped workers in the vicinity in regular employment which maintains approved labor standards for essentially the same type, quality and quantity of work, and 2) the wages being considered above as being paid to non-handicapped workers in the regular employment must be for work which is comparable to that performed in the workshop. Stated another way, what would the client be paid if he performed this same job in competitive employment?

When, to meet the needs of clients, a job is subdivided or supervision or inspection is increased to maintain quality, the job has been changed. It is no longer "like" its counterpart in competitive employment. But to establish this difference and establish a fair wage (fair to the workshop, its customer, and the client who should get accurate data about his competitive "worth"), the workshop must be prepared to document and quantify the differences or similarities between the workshop job and various competitive jobs. A scale for doing this is found on the next page.

Scale for Comparing the Content of Workshop Job Title: ______________________________
With Similar Competitive Employment Job Title: ______________________________
In the ______________________________ Company ______________________________ Date
Where $________ to $__________ per hour ($____ average) was paid to approximately __________ workers on this job
Who produced approximately ____________ to __________ pieces/items/operations per hour (____________ average)
Prepared by: ______________________________

	Degree of importance in the competitive job E-essential, key element N-necessary but less critical element H-helpful or minor U-unimportant (circle one for each job characteristic)	E = -15 N = -8 H = -1	-5 -2 0	0 0 0	+5 +2 0	+15 +8 +1	SPECIFIED VALUES FOR THIS REQUIREMENT Column A
		WEIGHTED VALUES (fill in values to match the circled degrees of importance)					
JOB CHARACTERISTICS		Much less in the workshop job	Less in the workshop job	same	More in the workshop job	Much more in the workshop job	
DATA RELATIONSHIPS							
1. Analyzing	E N H U						
2. Compiling	E N H U						
3. Computing	E N H U						
4. Copying	E N H U						
5. Comparing	E N H U						
6. PEOPLE RELATIONSHIPS	E N H U						
THINGS RELATIONSHIPS							
7. Precision Working	E N H U						
8. Operating-Controlling	E N H U						
9. Manipulating-Tending	E N H U						
10. Handling	E N H U						
11. Flexibility to do different kinds of work	E N H U						
QUALITY							
12. Degree of Perfection (amount of errors or flaws permitted short of being rejected)	E N H U						
		Much more in the workshop job	More in the workshop job	same	Less in the workshop job	Much less in the workshop job	
13. Number of rejects allowed	E N H U						
SUPERVISION							
14. Amount of time given worker		-25	-15	0	+15	+25	
15. Quality of supervisor		-10	-5	0	+5	+10	
16. Permanence or stability of employment (seasonal, temporary, intermittent)		-15	-5	0	+5	+15	

______ + 100 = ______ × $______ = $______ ÷ ______ = $______

Total of Column A

Avg or Selected Pay of competitive job

Base Pay for ___% output on workshop job

Expected output in pieces/hour

Piece rate for workshop job

Example:

The job of assembling the plastic toy in the workshop was studied. It was thought to be most like the job of assembling ball point pens which was being performed in the Ideal Manufacturing Company by about 12 production workers who are paid $2.15 an hour.

When an hourly based rate has been determined from an examination of competitive job comparisons, the piece rate is obtained by dividing it by the expected pieces per hour.

Example:

In the previous example, if the competitive labor rate was determined to be $1.90 per hour, the piece rate would be:

$$\frac{\text{Going Labor Rate}}{\text{Expected Pieces/Hour}} = \text{Piece Rate}$$

	Labor Going Rate	÷	Expected Pieces/Hr	=	Piece Rate/ea
Assembly	1.90		19		10¢
Packaging	1.90		64		3¢

14. WHAT ARE THE PRINCIPLES OF TIME STUDY?

If you have mastered the material up to this point, ending with the previous section on a "quick way to set production standards," you have finished the course of study.

Congratulations!

This section on time study and the ones to follow

15. What is work rating?
17. What allowances should be considered in setting production standards?

are for use by workshop personnel who desire to use more precise methods such as would be followed by the industrial time standards engineer to determine production standards.

The sections

16. What should be considered when using pre-determined time systems?
18. What factor should be considered for the learning curve?

are also for more advanced work. You may want to consider them if much of your time is spent estimating or setting production standards of estimating production outputs for pricing or bidding or production scheduling purposes.

Time study techniques are suggested for rehabilitation workshops because they require less training than pre-determined time methods and because they can be done relatively quickly with reasonably accurate results.

Four different kinds of time can occur in the making of any product. These are:

1. Cyclical elements: These elements occur at least once in every sequence or cycle of work. An example would be the use of a hand operated drill press being used to drill two holes in a piece of steel. The feed handle must be pulled down each time a hole is to be drilled. This pulling of the handle will occur two times in every piece of steel produced by this drill press operator. Pulling the handle is a cyclical element.

2. Non-cyclical elements: May occur once every two, five, ten, or any number of work sequences or cycles. An example in the drill press illustration would be the periodic replacement of the drill bit to replace with a sharpened one or the periodic refilling of the cutting oil reservoir. The refilling of a stapling machine is another example.

3. Avoidable delay: Are idle time, dropping tools, unnecessary moving or tasks done by the worker which is not required in the performance of his job.

4. Unavoidable delays: Are delays that are beyond the worker's control. Management must either eliminate them or allow time for them. An example would be waiting for inspection, or waiting for materials to be delivered or for finished products to be taken away from the work station.

Because they are most easily overlooked, the non-cyclical elements require special attention when the time studies are being used to prepare a bid on a new job. These include the time required to set up a job, the transportation of materials and finished parts from one work station to another, periodic lubrications of equipment or change of tools or cleaning, tear down and take away time when the job is completed, and many of the packaging, protecting, sealing, marking, and counting operations performed to prepare the item for shipment or delivery to the customer.

Time study observes and records the time required for the cyclical and non-cyclical elements in the performance of a job. The cyclical elements are most easily studied. Half or all day studies are preferred for accurate identification of the non-cyclical elements, when the job is important enough to justify it.

Time study is best done with the actual work. A pilot or sample run of a job for this purpose permits a better study and results in a more accurate production standard. This too leads to a better bid or price being established.

Steps in the time study process:

1. Completely describe work methods and working conditions
2. Break the job into elements
3. Measure actual time (observed time) required by a selected worker
4. Rate effort or pace
5. Calculate normal time
6. Determine appropriate allowances
7. Calculate standard time

In summary, time study is the technique for finding the time required.

By: a qualified, trainer worker

Working at: a normal pace or effort level

With specified: methods

materials

tools

equipment, and

working conditions

To do: a clearly defined unit of work

14A. HOW DO YOU USE A STOP WATCH?

There are two systems for using a stop watch.

In the "snap back timing" method, the stop watch hands are started from zero at the beginning of each element and snapped back to zero at the end of the element ready to run again for the next element. A reading of the watch is made just before the hands are snapped back and recorded in the "T" (for "time") column on the time study sheet with no further computation necessary. This system is criticized because of the fractional loss of time during the reading of the position of the hands.

The "continuous timing" method has the watch started from zero at the beginning of the first element, but instead of being returned to zero for each successive element the hand is permitted to continue to move. As each element is completed, a quick reading of the hands is made and recorded in the "R" (for "reading") column on the time sheet. When a series of up to 10 complete continuous cycles are recorded, the watch is stopped. The difference between readings for successive elements is then calculated and recorded in the "T" column.

If you do not have a stop watch, the sweep second hand on an ordinary watch can be used satisfactorily for most workshop time study jobs. It would be used as described for the stop watch continuous method with a reading and recording in seconds at the end of each successive element.

For very short elements, of 5 or 6 seconds duration or less, the methods of counting seconds may be satisfactory. If you say at a normal speaking speed, "one thousand one, one thousand two, one thousand three, one thousand four, etc.," you will be able with a little practice, to be 95-97% accurate (2-3 seconds error in one minute).

A Time Study Trainer Problem

The Time Study Trainer rotates a disc divided into eight colored sections. Each color represents a task or element which is to be timed with a stop watch or sweep second watch. The times obtained by you can be checked against known values at the end of the problem so you can judge your accuracy with the watch.

Put the names of the colors in the "elements" column on the Time Study Sheet. As the disc rotates, record the values from your watch (hundreths of a minute for the stop watch, seconds for the sweep second watch) in the "R" (reading) column nearest the "elements" column. You note the watch reading at the end of each color and record it opposite that color on the sheet. The reading at the end of each color is similarly recorded immediately below the previous one. At the end of the cycle, go to the top of the next "R" column and continue to record down that column for each color as before. When the last cycle has been timed, the values for the "T" (time) column are obtained by subtracting consecutive "R" figures.

One special note for those who use a sweep second watch. Because you cannot start your watch at zero, record the starting time in the upper half of the "R" box at the beginning of the first color in the first cycle. Then record the ending value in the lower half of the same box. This needs to be done only once for each timing session, to establish a value from which to subtract your first ending reading. From then on, in both the stop watch and sweep second watch methods, the ending time value automatically becomes the beginning value for the next color within a cycle and from one cycle to the next when the cycles follow each other without interruption.

After the "T" values have been computed, any widely deviant values are dropped and the remaining ones totaled for each color or element. The total is divided by the number of values used and an average time thus obtained for each color or element.

METHODS AND TIME STANDARDS
MANUFACTURING CONTROL

TIME STUDY COMPUTATION

PART NUMBER

ED. NUMBER

OPER. NUMBER

OPERATION DESCRIPTION

MATERIAL	FORM	HEAT TREAT 000 P.S.I.	VEHICLE	J.D. CARD

LOAD CENTER	DRAWING CHANGE NO.	INITIALS	DATE	START	STOP

ELEMENTS	R	T	R	T	R	T	R	T	R	T	F.E.	TOTAL TIME	NO. OF CYCLES	AVE. TIME	RATING	NORMAL TIME

TOTAL NORMAL TIME STUDY TIME ________________ ____

X DELAY ALLOWANCE FACTOR ________________ ____

X .0167 (min. to hrs.) ________________ ____

STANDARD HOURS ________________ ____

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METHODS AND TIME STANDARDS
MANUFACTURING CONTROL

TIME STUDY COMPUTATION

PART NUMBER

ED. NUMBER

OPER. NUMBER

OPERATION DESCRIPTION

MATERIAL

FORM

HEAT TREAT 000 P.S.I.

VEHICLE

J.D. CARD

LOAD CENTER

DRAWING CHANGE NO.

INITIALS

DATE

START

STOP

ELEMENTS	R	T	R	T	R	T	R	T	R	T	F.E.	TOTAL TIME	NO. OF CYCLES	AVE. TIME	RATING	NORMAL TIME

TOTAL NORMAL TIME STUDY TIME ______________
X DELAY ALLOWANCE FACTOR ______________
X .0167 (min. to hrs.) ______________
STANDARD HOURS ______________

METHODS AND TIME STANDARDS
MANUFACTURING CONTROL

TIME STUDY COMPUTATION

PART NUMBER

ED. NUMBER

OPER. NUMBER

OPERATION DESCRIPTION

MATERIAL	FORM	HEAT TREAT 000 P.S.I.	VEHICLE	J.D. CARD
LOAD CENTER	DRAWING CHANGE NO.	INITIALS	DATE	START	STOP

ELEMENTS	R	T	R	T	R	T	R	T	R	T	F.E.	TOTAL TIME	NO. OF CYCLES	AVE. TIME	RATING	NORMAL TIME

TOTAL NORMAL TIME STUDY TIME ______

X DELAY ALLOWANCE FACTOR ______

X .0167 (min. to hrs.) ______

STANDARD HOURS ______

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15. WHAT IS WORK RATING?

We all know there is a wide difference in the speed at which people work. Studies have shown that in industry the fastest worker will produce about twice as much as the slowest. You know from your own experience that some days you can accomplish more than on other days. Your mood, attitudes, whether you are refreshed or tired--all effect your performance. Couple these factors with the wide range of skills which different people possess and it provides an explanation of the wide variation in performance which is to be expected from workers.

Rating is the comparison of the speed of a worker to the observer's concept of normal working speed. Normal working speed is not that which can only be done by a superman. It is a comfortable pace which can be kept up all day without unusual fatigue. In some jobs such as typing, a minimum speed is necessary to maintain rhythm. In others such as shoveling dirt, effort must be controlled to prevent energy burnout.

Standardized rating practice exercises have been developed to assist your learning this normal working speed concept. All work rating exercises involve tasks for which normal times have been developed by comparing the opinions of thousands of industrial engineers. These agreed upon norms represent their concept of an average working speed or pace.

Rating can be learned quickly but it is necessary to refresh your memory by using one or more of the rating exercises before you start time studies. This is especially important if you do not make many time studies.

Three of the more common of these exercises are described on the next few pages.

15A. HOW CAN YOU PRACTICE WORK RATING?

Walking

Measure either a 44 or 50 foot distance. Place two chairs about three feet apart at either end of this distance. Stretch pieces of string across the three foot space between the seats of the chairs. The string may be held in place by putting a book or similar object on top of it as it rests on the chair seat.

Thus, a person who walks along the measured distance will hit the string with his legs and pull it from under the book as he walks between the chairs at both the beginning and end of the course.

Have the person who walks the course start eight to ten feet in front of the starting point so he is traveling at a regular gait when he hits the starting string. He should continue at a uniform speed and walk on through the string at the end of the course.

One or more of the observers should use either stop watches or a sweep second hand watch to record the exact walking time from one string to the other.

Each observer and the person walking should form an opinion of the speed of of the walker. This, when expressed as a rating, uses 100% to represent an average person's normal walking speed. If you think he walked about 10% faster than normal, you would rate it 110%. If you thought he was slow, your rating could be 80% to represent a walking speed only 4/5 as fast as normal. Important: Do not look at the time-figure for the walking until you have recorded your observed rating percentage on the Rating Practice sheet, see page 90.

The time for the walk can now be found on the Table of Time Values and Ratings, page 89. Reading across the horizontal line to the column on the left will reveal the true rating which should also be recorded on your Rating Practice sheet.

Subtract the true rating from your observed rating to determine the difference and direction of your judgment error. A plus difference indicates you have over rated the walking, that is rated it too high. A minus difference indicates that you rated the walking as being slower than it actually was.

Walking on the level without a load at three miles per hour is considered normal or 100%.

Card Dealing

Use a relatively new deck of 52 playing cards. Deal the cards one at a time into four separate piles around the corners of a one foot square. Hold the pack stationery about 12 inches from the center of the square. The dealing hand should place each card on its pile. Do not toss the cards from a distance.

Make and record observed rating judgments and use time values to find true rating percentages as described in the walking exercise.

Because the method of dealing and condition of the cards can influence the time, card dealing is not considered to be as valid as the pegboard exercise described next.

The 52 cards require 0.5 minutes or 30 seconds to deal at normal or 100%.

Pegboard

The 30-peg pegboard described in Section 10A or a similar 60-peg pegboard with ten vertical rows of six pegs each is an inexpensive and effective rating practice device. It is especially useful when finger, hand, and arm dexterity and coordination jobs are to be performed.

A pin is to be picked up by each hand simultaneously from the supply box located next to the pegboard on the side away from the operator. The pegs are to be put rounded end down into the beveled holes of the pegboard starting with the holes in the center of the board next to the operator. Fill the vertical rows working successively away from the operator. When the row is filled, start the rows immediately next to the rows just filled, again beginning with the holes next to the operator and working away from him.

Make and record observed ratings and use the time values to find the true rating as described in the walking exercise.

For All Exercises

Repeat each exercise used at least ten times. Vary the speed of performance within an 85% to 150% range so both observer and performer can achieve accuracy within 5-10% for a variety of speeds.

Table of Time Values for Different Ratings

Using a Stop Watch
(time in minutes)

Rating	WALK		PEGBOARD		Card Dealing
	44 ft.	50 ft.	30 Pegs	60 Pegs	52 Cards
50%	.33	.38	.82		1.00
60	.29	.32	.68		.83
70	.24	.27	.59	1.20	.71
75				1.12	
80	.21	.24	.51	1.05	.63
85				.99	
90	.18	.21	.46	.93	.56
95				.89	
100	.17	.19	.41	.84	.50
105				.80	
110	.15	.17	.37	.76	.46
115				.73	
120	.13	.16	.34	.70	.42
125				.67	
130	.12	.15	.32	.65	.39
135				.62	
140	.12	.14	.30	.60	.36
150	.11	.13	.27		.33

Using A Watch With A Sweep Second Hand
(time in seconds)

Rating	WALK		PEGBOARD		Card Dealing
	44 ft.	50 ft.	30 Pegs	60 Pegs	52 Cards
50%	20	23	49		60
60	17	19	41		50
70	15	16	35		43
75			33		
80	13	14	31		38
85			29		
90	11	13	27		33
95			26		
100	10	12	25		30
105			23		
110	9	10	22		27
115			21		
120	8	10	21		25
130	8	9	19		23
140	7	8	18		22
150	7	8	16		20

RATING PRACTICE

Task ____________________

Trial	Observed Rating	True Rating	+ - Difference
1			
2			
3			
4			
5			

Task ____________________

1			
2			
3			
4			
5			

Task ____________________

1			
2			
3			
4			
5			

Task ____________________

1			
2			
3			
4			
5			

Task ____________________

1			
2			
3			
4			
5			

RATING PRACTICE

Task____________________________________

Trial	Observed Rating	True Rating	+ - Difference
1			
2			
3			
4			
5			

Task____________________________________

1			
2			
3			
4			
5			

Task____________________________________

1			
2			
3			
4			
5			

Task____________________________________

1			
2			
3			
4			
5			

Task____________________________________

1			
2			
3			
4			
5			

RATING PRACTICE

Task____

Trial	Observed Rating	True Rating	+ - Difference
1			
2			
3			
4			
5			

Task____

1			
2			
3			
4			
5			

Task____

1			
2			
3			
4			
5			

Task____

1			
2			
3			
4			
5			

Task____

1			
2			
3			
4			
5			

The film, MULTIPLE VIEW TIME STUDY, Number UC-904 may be rented for $10.00 per showing from the University of California, Extension Media Center, Berkeley, California 94720.

The film simultaneously shows six views of an operator moving steel balls to a rotating index plate (load index plate bimanually). In the first half of the film, each view is labeled with the worker's rating ranging from 70% to 145% in 15% steps. In the second half of the film, the viewer is to assign ratings to each of the views for comparison with the true values which are furnished in the instructions.

Another film, TIME STUDY RATING, Number UC-903, may be rented for $11.00 per showing from the University of California as above.

It shows 30 full screen trials of the operation described above for the viewer to rate. The first scene is a 100% performance. True ratings are furnished in the instructions for comparison and analysis.

The 1965 series films on DIRECT, INDIRECT, AND CLERICAL OPERATIONS were prepared by the Society for the Advancement of Management. There are six films in the series, each of which may be rented for $5.00 per showing from the Rehabilitation Workshop Administration, University of San Francisco, 2130 Fulton Street, San Francisco, California 94117.

These films show 5 different rated speeds of 18 jobs as follows:

Film 1: Mail Sorting, Manual Typing, Filing

Film 2: Comptometer, Key Punch, Check Writing

Film 3: Drill Press, Turret Lathe, Punch Press

Film 4: Mechanical Assembly, Engraving, Form Rug Cup

Film 5: Sweep Floors, Wash Windows, Mop Floor

Film 6: Pack Cans, Seal Cartons, Stack Cartons

TIME STUDY RATING EXERCISE

Load Index Plate Bimanually

	1st	2nd	actual
#1			
2			
3			
4			
5			
Total			
Average			

Your average minus actual average equals your accuracy

#1st ____ - ____ = ____%

2nd ____ - ____ = ____%

3rd ____ - ____ = ____%

4th ____ - ____ = ____%

	3rd	actual	4th
#1			
2			
3			
4			
5			
6			
7			
8			
9			
10			
11			
12			
13			
14			
15			
16			
17			
18			
19			
20			
21			
22			
23			
24			
25			
26			
27			
28			
29			
30			
Total			
Average			

15B. HOW CAN YOU RELATE ACTUAL TIME TO NORMAL TIME?

Actual or observed time (from the time study) is the time taken by a given worker to do a task. Normal time is the time it will take an average worker who is skilled in his classification and is familiar with the job to do the task.

The actual time taken by such an average workman, often called a 100% worker, is thus the same as the normal time. If, however, the worker is above average, he will complete the task in less time. The actual, observed time for his performance must be adjusted upward to obtain normal time or the time expected of a 100% worker. Similarly, a below average worker will take more time on a task. His actual observed time needs to be reduced to obtain normal time.

To make the adjustment from actual time to normal time, you:

1. Start with actual time (observed time) in minutes or seconds.
2. Multiply times the rating in decimal form
3. Answer is normal time in minutes or seconds

Formula:

ACTUAL TIME (in minutes or seconds) X RATING (a decimal) = NORMAL TIME (in minutes or seconds)

Example:

A worker packed a bag in 12 seconds and is rated as working at 2/3 of normal or 67%. The normal time for packing the bag should be 8 seconds.

12 x .67 = 8

Example:

A worker is timed at 0.3 minutes while assembling an item and is rated as working at 110% of normal. The normal time for assembly should be 0.33 minutes.

.3 x 1.10 = .33

If you time and rate three or more persons on a job, you should obtain a reasonably uniform normal time from each calculation. A significant variation in the calculated normal times would indicate that either the method employed by each person was different and/or the rating assigned to each was faulty. It is harder to accurately rate people who are very fast or very slow, so be cautious with persons who fall into these extreme categories.

16. WHAT SHOULD BE CONSIDERED WHEN USING PRE-DETERMINED TIME SYSTEMS?

Pre-determined time systems, such as MTM, PMD, or PMT, require considerable skill and relatively long periods of time to complete when the job to be studied is an elaborate one. They are most useful when the job involves a large amount of labor on a relatively simple operation. If the work to be performed is relatively complex, the time required to prepare them and, hence, the cost can quickly become prohibitive unless the production run is long enough to justify the study.

The chief benefit which pre-determined time systems provide is the freedom from the need to rate the performance of work. The time values for each predetermined time motion have already been normalized and reflect the time for an average workman to perform such a movement. This characteristic would make predetermined time systems of value for workshops with severely handicapped clients whose rate of performance is considerably different from that of normal and where, as a result, the process of rating them becomes more difficult.

If the work on an item requires a long series of operations or steps, predetermined time systems can be of use in balancing a production line where a number of workmen each perform successive pieces of the total job. With time study, it is more difficult to time sub-elements or parts of a job. In predetermined time, sub-division comes naturally from the technique. Thus, the job can be split into equal portions of work. This characteristic is particularly helpful in establishing fair hourly rates of pay for a group of workers on an assembly line. It also can help to equitably distribute the work elements among the workers in order to get maximum total production from the group.

17. WHAT ALLOWANCES SHOULD BE CONSIDERED IN SETTING PERFORMANCE STANDARDS?

The most common types of industrial allowances are for personal time, fatigue, minor delays, and unavoidable delays.

A learning factor is felt to be needed in most workshops to correct for the frequent short production runs.

Personal allowances provide time for personal needs such as going to the rest-room, pausing for refreshments, or socializing.

Fatigue allowances are the most difficult to determine. Excessive physical fatigue is disappearing in industry with the expanded use of machinery and because of unavoidable delays which give the worker some resting time. Under extreme working conditions, such as in frozen food plants, steel mills, and heavy labor work, a worker is granted a 50% allowance which means he is only expected to work half of the time.

Minor delay allowances are sometimes provided for getting personal tools ready for use, get-ready time in the morning, and clean-up time at night. This allowance is best determined by time studying several workers for a full day's shift.

Unavoidable delay is used to make it possible for a normal worker to reach 100% performance for the entire shift. This allowance covers delays caused by conditions beyond the employee's control. Waiting for job assignment, waiting for tools, waiting for materials, and waiting for inspection are typical examples of unavoidable delays. These delays are management problems. It is management's responsibility to be aware of them and to keep them to a minimum.

Another time adjustment exists which most rehabilitation workshops ignore. This is a factor based on the learning curve. It is of particular importance to workshops because many of the jobs which they perform are of the short duration type. Industry minimizes the problem by scheduling long sustained production runs. It thus permits its workers to become thoroughly skilled in the job they are to perform. This is seldom done in a workshop. Although the length of time to learn a job will vary with the complexity and the degree of skill required by it, there is a uniform pattern in all learning. This pattern is characterized by rapid improvements at first and then a gradually slowing rate of improvement over continued time. Sometimes plateaus occur when improvements are temporarily stymied. These are then followed by a new increase in skill when mastery of previous work is secured. Such a stair-step pattern of improvement and plateau followed by improvement and another plateau, and so forth, is to be expected. Section 18 will deal with mathematical corrections which can be made for the learning curve.

17A. HOW MUCH TIME SHOULD BE GIVEN FOR ALLOWANCES?

There are three factors which influence the amount of time which is permitted a worker for non-productive purposes.

1. The degree of competition experienced by the company in its own field.

2. The accuracy or relative tightness of looseness of time standards which have been set.

3. The frequency of job changes or the length of production runs.

In some industries (for example the sewing or the food processing industries) competition is so keen and profit margins so narrow that workers are expected to and do produce with very tight and demanding time standards. Output must be very high and wasted or lost time held to an absolute minimum for the worker to be able to earn a full day's wage in this type of work. By contrast, there are jobs (such as in some of the aero-space industries and in-service occupations) where the employee is under considerably less pressure to be productive each moment of his work day.

Although most workshops assume and are often led to believe by their customers that they fall into the first category, it is probably more accurate to view them as in an industry where relatively loose time standards prevail. This is partly because of the nature of the work and partly because of the "nuisance" or short run characteristics of the jobs performed in the workshop. Learning time, set up and start up time, and supervision must be high in this kind of work whether done by industry or by a workshop.

The typical time allowed for personal allowances will range between 4 to 10%, depending primarily on the frequency and length of coffee or rest breaks. Coffee breaks lasting 15 minutes each would account for almost 7% of such an allowance.

Fatigue allowances should be relatively short in rehabilitation workshops. Values ranging between 2 to 6% (between nine and twenty-nine minutes per day) should be considered adequate.

Time for minor delays and unavoidable delays should reflect the efficiency of making and changing job assignments, of delivering materials to the workers, and of the maintenance of equipment in general. While it is management's job to keep these delays at a minimum, it is generally true that rehabilitation workshops do a much poorer job of this than does industry in general. For this reason, it seems appropriate to use relatively high allowances in this category pending the improvement of supervisory and management skills. A 5% delay allowance would be a reasonable goal to seek to achieve, but 10 to 20% is a more likely figure for the present state of rehabilitation workshop managerial efficiency.

In total, then, allowances would range from a low of 11% to a high of about 26%. In practice, about 15% is a fairly competitive allowance figure with 25% a more reasonable average for present workshops. The exact figure, obviously, must be tailored to the workshop itself.

17B. HOW CAN YOU RELATE NORMAL TIME TO STANDARD TIME?

Normal time represents the amount of time required by a trained, average workman to do a given task. Standard time takes into account the time required for the various allowances. To compute the standard time, you:

1. Start with normal time in minutes and seconds

2. Multiply times the allowance in decimal form

3. Add the original normal time

4. The answer is standard time in minutes or seconds

Formula:

NORMAL TIME (in minutes or seconds) x ALLOWANCE FACTOR (a decimal) + NORMAL TIME (in minutes or seconds) = STANDARD TIME (in minutes or seconds)

Example:

The calculated normal time for a worker to pack a bag is 8 seconds. The workshop figures a 25% allowance factor. The standard time for packing the bag should be 10 seconds.

$$(8 \times .25) + 8 = 10$$

Example:

A worker's normal time for assembly of an item is .33 minutes. A 15% allowance for personal time, fatigue, and delays is recognized by the workshop. The standard time to assemble it is .38 minutes.

$$(.33 \times 15) + .33 = .38$$

17C. HOW CAN YOU CALCULATE STANDARD HOURS?

The standard hours value is the length of time in hours required to do a job or to produce a product by an average, trained workman who is granted necessary allowances.

Standard hours are computed by:

1. Start with the standard time in minutes or seconds.
2. Divide by 60 (for standard minutes) or by 3600 (for standard seconds)
3. The answer is standard hours

Formula:

$$\frac{\text{STANDARD TIME (in minutes)}}{60} \text{ or } \frac{\text{STANDARD TIME (in seconds)}}{3600} = \text{STANDARD HOURS}$$

Example:

A standard time of 10 seconds is calculated for packing bags. The average worker will require .00277 standard hours to do this job.

$$\frac{10}{3600} = 0.00277$$

Example:

A standard time of .38 minutes is calculated for assembly of an item. An average, 100% worker will require .0063 standard hours to do this job.

$$\frac{.38}{60} = .0063$$

17D. HOW CAN YOU CALCULATE EXPECTED OUTPUT PER HOUR?

Standard time values can be used to compute production standards. It is done as follows:

1. Start with standard time in minutes or seconds or hours
2. Divide into 60 (for minutes) or 3600 (for seconds) to get hourly output from an average 100% worker, or
3. Divide standard hours into 1 (or find the reciprocal of the standard hours in a math book) to get hourly output from an average worker

Formula:

$$\frac{60}{\text{STANDARD TIME (In minutes)}} = \text{UNITS OF OUTPUT PER HOUR}$$

Or:

$$\frac{60}{\text{STANDARD TIME (In seconds)}} = \text{UNITS OF OUTPUT PER HOUR}$$

Or:

$$\frac{1}{\text{STANDARD HOURS}} = \text{UNITS OF OUTPUT PER HOUR}$$

Example:

A standard time of 10 seconds or .00277 standard hours is calculated for packing bags. The average worker on this job should produce 360 bags per hour.

$$\frac{3600}{10} = 360 \qquad \text{Also} \qquad \frac{1}{.00277} = 360$$

Example:

Assembling an item was calculated to require a standard time of .38 minutes of .0633 standard hours. 157 items per hour should be assembled by 100% workers.

$\frac{60}{.38} = 157$ Also $\frac{1}{.0063} = 157$

18. WHAT FACTOR SHOULD BE CONSIDERED FOR THE LEARNING CURVE?

As a person repeats the same task over and over again, he usually takes progressively less time for each complete work cycle. This improvement which comes with practice is due to the fact that we "train" our muscles and brain to automatically perform the manipulations and mental matchings required by the job. The more training provided, the more automatic the process becomes.

It has been found that a mathematical relationship exists between the length of time required to perform a task and the number of times the task has been performed. The Quantity Factors on the next page, have been derived from this learning curve theorem as described in How to Use the Learning Curve by Raymond Jordan as published by the Materials Management Institutes, Boston, Mass. The Theorem states that beyond about 16 operations, everytime the number of operations performed by a worker doubles, the new cumulative average time required for the operation declines by a fixed percent of the previous cumulative average time. This fixed percentage has been called the learning curve. The amount of the percentage will vary in ordinary work from 85% for complex jobs to 95% for quite simple jobs.

An illustration of the learning curve for an in-between job, somewhere midway between a complex and a simple job, would be as follows:

> A job consists of the assembly of an intricate toy train locomotive involving 47 parts. Some of the parts require screwdriver and small wrench fabrication. Others are glued. A few are soldered. The 90% learning curve has been found to be applicable.

QUANTITY FACTORS

For adjusting from small lot test runs to larger lot sizes (use with average time per unit or average quantity produced per hour)

Lot Size (Quantity of Units)	Complex Jobs*	Average Jobs**	Simple Jobs***
8000-15999	0.9	0.8	0.85
4000-7999	1.0	0.9	0.90
2000-3999	1.2	1.0	0.95
1000-1999	1.3	1.1	1.00
500-999	1.5	1.2	1.05
250-499	1.7	1.4	1.11
125-249	2.0	1.5	1.17
60-124	2.3	1.7	1.24
30-59	2.6	1.9	1.30
16-29	3.0	2.1	1.41
8-15	3.5	2.3	1.48
4-7	4.0	2.6	1.56
2-3	4.6	2.8	1.65
1	5.3	3.2	1.74

*Based on 87% learning curve
**Based on 90% learning curve
***Based on 95% learning curve

(Where with each doubling of production, the new cumulative average time per unit declines to this percentage of the previous cumulative average.)

Formulas:

1) If average time per unit is known for the units in a small lot:

$$\frac{\text{Quantity Factor for Small Lot}}{\text{Average time/Unit for Small Lot}} = \frac{\text{Quantity Factor for Larger Lot}}{\text{Average Time/Unit for Larger Lot}}$$

2) If average quantity produced per hour is known for the small lot:

$$\frac{\text{Quantity Factor for Small Lot}}{\text{Average Quantity Produced/Hour for Larger Lot}} = \frac{\text{Quantity Factor for Larger Lot}}{\text{Average Quantity Produced/Hour for Small Lot}}$$

When a person assemble:	Total Time Required (Minutes)	His avergae cumulative time for ea. unit is: (Minutes)	The ratio of the new cumulative avg. time compared with the previous cumulative avg. time
16 locomotives	1600	100	
32 "	2880	90	90%
64 "	5184	81	90%
128 "	9331	72.9	90%
256 "	16794	65.6	90%
512 "	30208	59	90%
1024 "	54374	53.1	90%

These relationships have been summarized in the following table of factors which make it possible to:

1. Predict the average time per item for a larger production run of a job when the average time per item is known from a sample or test run.
2. Estimate the average time per item expected to be achieved by a worker on a new job assignment when the average time per item is known for an experienced worker.

To use the quantity factors table, first select the learning curve percentage which appears to be suitable for the job's complexity. When in doubt, use the 90% learning curve column.

Next, enter the factors from the table in the appropriate formula along with the time value which is known. The other time value can then be calculated by solving the formula with ordinary algebra.

Example:

In a sample production run of 30 items, a total of 5 hours was worked by one worker. The production supervisor needs to predict how long it will take this worker to make 500 items.

Since 30 items were made in 300 minutes (5 hours x 60 minutes/hr), the average time per item was 10 minutes.

$$\frac{300\text{ total minutes}}{30\text{ items}} = 10\text{ min/item}$$

This is put into formula #1 as the average time per unit for small lot.

$$\frac{\qquad\qquad}{10\text{ minutes}} = \underline{\qquad\qquad}$$

The small lot of 30 items (the sample run) is in the range of 30-59 on the table. The factor on the line opposite the 30-59 range in the average job column is 1.9. This is put into the formula as the "quantity factor for small lot."

$$\frac{1.9}{10\text{ minutes}} = \underline{\qquad\qquad}$$

The large lot of 500 (the future production run) is in the 500-999 range. The factor opposite his range in the average job column is 1.2. Putting this in the formula makes it look like:

$$\frac{1.9}{10\text{ minutes}} = \frac{1.2}{\qquad\qquad}$$

Solving the formula be letting "x" stand for the average cumulative time for each item when a lot of 500 are produced is done by:

$$\frac{1.9}{10} = \frac{1.2}{x\text{ minutes}}$$

$$1.9x = (1.2)\ (10)$$
$$1.9x = 12$$
$$x = 6.3\text{ min/item}$$

Thus, the 500 items will be made with an average time of 6.3 minutes per each. The entire 500 items will take 3150 minutes or 52 hours and 30 minutes.

(500 items x 6.3 min. = 3150 min.)

Example:

Experienced workers take and average of 6 minutes per item to do lots of 3000 items. The item is fairly complex, requiring considerable work skill. How much time should a new worker take when he has completed his first 16 items? 32 items? 64 items?

For the 16 items calculation, using the "complex job" column:

$$\frac{3.0}{x \text{ minutes}} = \frac{1.2}{6 \text{ minutes}}$$

$$\begin{aligned} 1.2x &= (3.0)\ (6) \\ 1.2x &= 18 \\ x &= 15 \text{ min/item} \end{aligned}$$

For the 32 items:

$$\frac{2.6}{x \text{ minutes}} = \frac{1.2}{6}$$

$$\begin{aligned} 1.2x &= 15.6 \\ x &= 13 \text{ min/item} \end{aligned}$$

For the 64 items:

$$\frac{2.3}{x \text{ minutes}} = \frac{1.2}{6}$$

$$\begin{aligned} 1.2x &= 13.8 \\ x &= 11.5 \text{ min/item} \end{aligned}$$

Formula #2 which can be used with this table of factors relates to the average number of items made per hour by one worker at various production run lot sizes. The formula is used in the same way as described in the previous examples except that the average quantity of items produced per hour is inserted and solved for rather than the average time per item.

Example:

In a test production run, 2¼ hours were required to make 100 fairly simple items. How long will it take one person to make 500 items?

$$\frac{\text{total items made}}{\text{total time required}} = \begin{array}{l}\text{number of items made}\\ \text{per hour in test run}\end{array}$$

$$\frac{100}{2.25} - 44 \text{ items per hour}$$

Using formula #2:

$$\frac{1.24}{x} = \frac{.9}{44}$$

$19x = 54.56$
$x = 66$ items/hour

$$\frac{\text{total items to be made}}{\text{output per hour}} = \text{Hours of work required}$$

$$\frac{5000}{65} = 75.8 \text{ hours for the 5000 lot}$$

A further use of these learning curve calculations permits you to predict the average time required to make one item when the average cumulative time is known.

It is reasonably accurate to say that the average cumulative time per item for one lot size range on the table is the same as the time per item for the middle item in the next smaller lot size range.

Example:

Assume that it has been calculated that the average cumulative time for 500 items is 6.3 minutes per item. Since 500 items is in the 500-999 lot size range, the middle item in the next smaller lot size range (250-499) is 375. Thus, the 375th item should take about 6.3 minutes to be made, the same as the average cumulative time per item for the 500 items. It must be recognized that these values are approximations for rough comparisons only.